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Evaluation of Upland Disposal of Richmond Harbor, California, Sediment from Santa Fe Channel

*by C. R. Lee, D. L. Brandon, H. E. Tatem,
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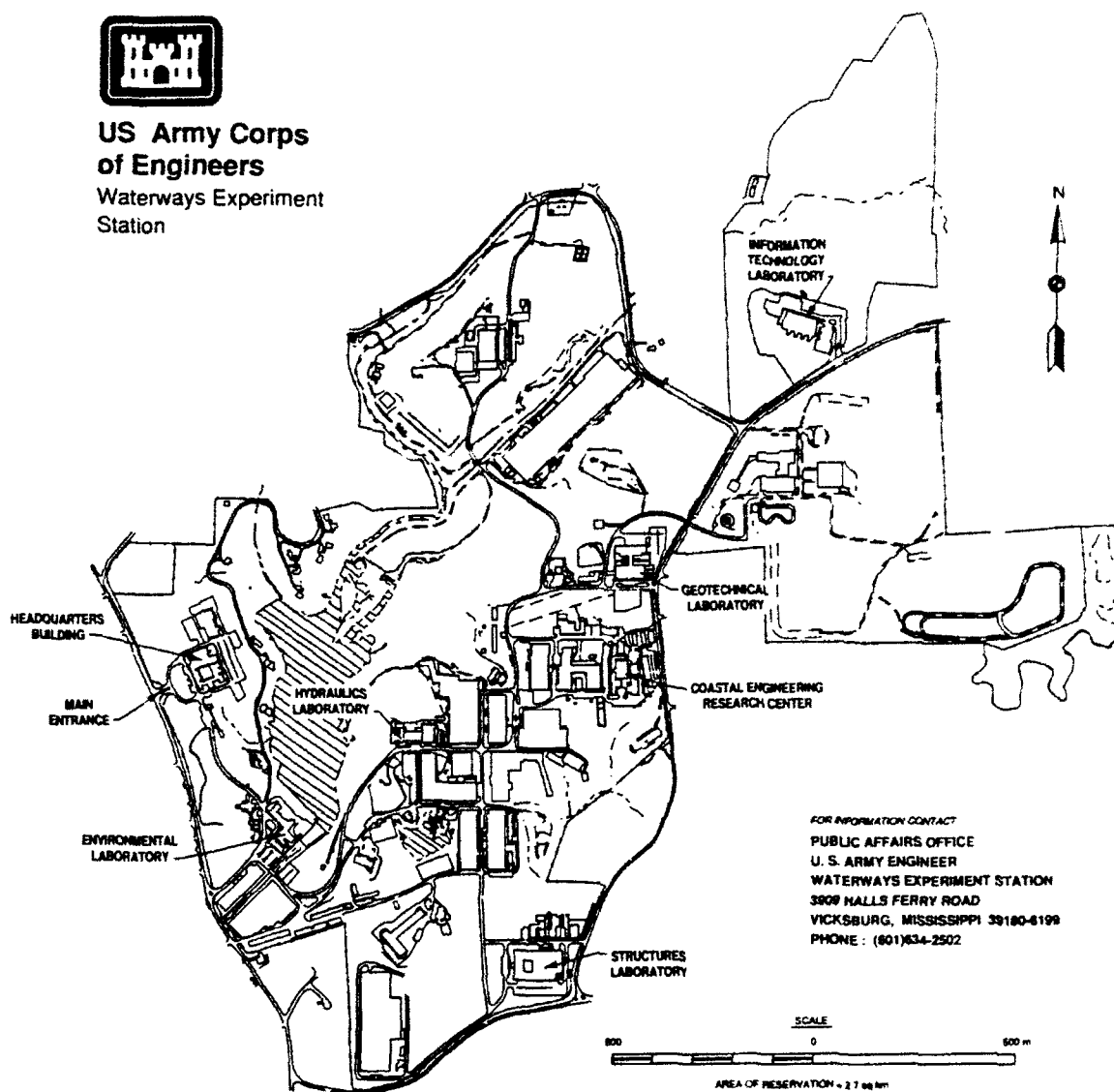
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SUMMARY

The construction of Richmond Harbor and Santa Fe Channel Project was authorized by Congress in 1930. As part of its responsibility for maintaining navigable waterways, the U.S. Army Engineer District, San Francisco, plans to deepen Richmond Harbor and Santa Fe Channels located on the northeastern edge of San Francisco Bay in Richmond, CA. Both channels would be deepened to -38 ft mean lower low water (MLLW) from the presently authorized depth of -35 ft MLLW. In addition, a turning basin will be dredged to -38 ft east of Point Potrero, and the southwestern junction of Santa Fe and Richmond Harbor Channels will be widened and deepened to -38 ft MLLW. The proposed turning basin and widening area have not been dredged previously. Dredging will produce approximately 1.5 million cubic yards of material that will require disposal.

The U.S. Army Engineer Waterways Experiment Station (WES) was asked to assist in the evaluation of other alternatives, such as upland disposal, for these sediments. Francingues et al. (1985) and Lee et al. (1991) described the Corps' Management Strategy for Disposal of Dredged Material, in which a sediment is tested and evaluated for potential disposal site environments, including aquatic, wetland, and upland. The upland test protocols were used in the present evaluation to determine the potential for migration of contaminants into effluent, surface runoff, and leachate at an upland disposal site.

The purpose of this report is to describe the results of a comprehensive evaluation of the impact of placing Santa Fe Channel sediment in an upland disposal environment. Contaminant migration via effluent, surface runoff, and leachate was evaluated. The upland disposal site would be managed such that plants and animals would not be allowed to colonize the site. Consequently, no upland plant and animal bioassay tests were conducted. Contaminants of concern were salt, metals, tributyltin, pesticides (particularly DDT and its derivatives), and polycyclic aromatic hydrocarbons (PAHs). Sediment was collected from Santa Fe Channel from core depths to -38 ft and transported to the WES for testing.

Santa Fe Channel sediment metal concentrations were found to be in the range of those found in normal agricultural soils with the exception of nickel. Santa Fe Channel sediment contains nickel concentrations at the maximum concentration allowed in soils for agricultural production.

Sediment butyltin concentrations were low, at 15 ppb, but were higher than those found at an upland reference disposal site at Twitchell Island. Santa Fe channel sediment contained some PAHs at concentrations higher than Twitchell Island and were generally elevated in PAHs compared to other reference sediments. Santa Fe sediment contained 185 ppb DDT, and 202 ppb DDD, which has given rise to concern.

Test results were interpreted in relation to existing Federal criteria and/or State standards, or existing related data and information from literature and past or present research projects. Because the disposal site is not known, test results of water quality data from filtered water samples were evaluated in relationship to Federal Water Quality Criteria and/or State Water Quality Standards for effluents and receiving waters. Test results were compared to the EPA Acute Water Quality Criteria for the Protection of Aquatic Life (USEPA 1987), and the Effluent and Receiving Water Limitations for Waste Discharge issued by the California Regional Water Quality Control Board in response to a permit application by the Port of Oakland for the disposal of Oakland Harbor sediment as levee-building material at Twitchell Island in the Sacramento River Delta. In the absence of State Water Quality Standards for an undetermined disposal site, the Federal Water Quality Criteria were assumed to be applicable to give some perspective to test results. Section 401 requires compliance with State Water Quality Standards, rather than Federal Water Quality Criteria. Final effluent limitations will be determined by the state under Section 401 of the Clean Water Act based on the local water quality objectives applicable to the area where the sediment is placed. These laboratory tests give predictions of water quality for specific conditions and should be considered an indication of the potential of an effluent, surface runoff, or leachate to meet or exceed applicable water quality standards.

The evaluation of the effluent to be discharged from an upland confinement indicated that, with the exception of copper for the Santa Fe channel sediment, the effluent will meet all assumed water quality criteria and standards prior to discharge. The concentrations of dissolved copper exceeding assumed criteria will require a dilution of up to 2 in the mixing zone to meet the criterion. This degree of mixing can generally be achieved within a short distance of the effluent discharge.

The total mass release of contaminants as effluent was estimated to be generally less than 3 percent of the total contaminants placed, and varied with respect to the assumed concentration of total suspended solids (TSS) in

the effluent. The placement operation should be managed to reduce the TSS concentration in the effluent to the largest degree practical. This can be accomplished by ponding effluent water within the confined disposal site prior to discharge. The resulting sedimentation of suspended solids should reduce the total mass release of contaminants.

Neomysis exposed to modified elutriate made from the Santa Fe channel sediment demonstrated no toxicity. Upland disposal effluent resulting from the Santa Fe Channel sediment therefore appears to have very little potential for adversely affecting marine aquatic organisms.

Contaminants in surface runoff from the Santa Fe Channel sediment were mostly bound to the sediment particulates. Significant quantities of arsenic, cadmium, chromium, copper, zinc, tributyltin, and 4,4-DDT could be eroded from an upland disposal site during the wet, unoxidized stage if the suspended solids were not removed from the runoff. Only arsenic exceeded any of the assumed criteria or standards for soluble contaminants. Potential surface runoff water quality problems during the wet, unoxidized period of upland disposal would therefore be mostly associated with erosion of particulates. Management of the upland disposal site to remove particulates from surface runoff would remove 90 to 99 percent of all contaminants in surface runoff. A very small mixing zone ratio of 3 to 1 would be required to dilute soluble arsenic to the assumed Receiving Water Quality Limitation standard.

Potential contaminant migration problems in surface runoff from dry, oxidized sediments are similar to those in surface runoff from the wet, unoxidized sediment. Again, only soluble arsenic exceeded the Receiving Water Quality Limitation standard for Santa Fe Channel sediment. Consideration of a small mixing zone and removal of the suspended solids should eliminate the need for further restrictions, particularly with regard to treatment of soluble contaminants. A mixing zone of less than 10 to 1 would be required to dilute unfiltered contaminant concentrations to less than or equal to the strictest assumed criteria or standards, and a mixing zone of about 3 to 1 would be required for soluble arsenic.

Exposure of sensitive test animals to Santa Fe Channel sediment runoff water showed little potential for aquatic toxicity. Mean survival was usually greater than 90 percent for all treatments. These bioassays indicate no potential for aquatic toxicity associated with this runoff water.

Sequential batch and column leach tests indicated a complicated leaching process for contaminants in Santa Fe Channel sediment. A progressive increase

in contaminant concentrations was observed as the sediment was washed in sequential batch leach tests or continuously washed in column leach tests. The batch tests indicated that peak concentrations occurred after most of the sediments salt was washed out. Thereafter, concentrations tended to decrease. Column leach data were in general agreement with increasing concentration trends followed by decreasing concentration trends, although the duration of the column tests was not sufficient to establish decreasing trends for some contaminants.

For the type of leaching behavior observed, initial pore water quality in a confined disposal facility for Santa Fe Channel sediment does not represent worst-case leachate quality. Leachate quality will get progressively worse until the salt content of the sediment has been removed. When sufficient rainwater has percolated through the dredged material for peak contaminant concentrations to occur (probably hundreds of years), present drinking water criteria for arsenic and chromium will probably be exceeded. The time required to reach maximum leachate contaminant concentrations may be on the order of hundreds of years, depending on climatic conditions and disposal site-specific engineering controls.

Evaluation of leachate controls using the Hydrologic Evaluation of Landfill Performance (HELP) computer model showed that initial leachate generation is primarily due to drainage of excess water in the dredged material. Leachate generation rates can be reduced by reducing the surface area of the disposal site and by constructing a composite liner.

In summary, Santa Fe Channel sediments will require management of suspended solids in effluent and surface runoff and a mixing zone of less than 10 to 1 to meet the strictest assumed water quality criterion or standard. Depending on the location, the confined disposal site should have a reduced surface area and a composite liner to control leachate migration, especially if leachate can migrate to surface receiving waters.

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PREFACE

This report presents the results of an evaluation of upland disposal of sediment from the Santa Fe channel of Richmond Harbor, California, performed for Ms. Maggi Kit, project manager, U.S. Army Engineer District, San Francisco. The study was conducted by the Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES).

Work was performed by Dr. Charles R. Lee, Soil Scientist, Mr. Dennis L. Brandon, Statistician, Dr. Henry E. Tatem, Zoologist, Mr. John G. Skogerboe, Physical Scientist, and Dr. James M. Brannon, Research Chemist, all of the Environmental Processes and Effects Division (EPED), and by Dr. Michael R. Palermo, Research Civil Engineer, and Mr. Tommy E. Myers, Environmental Engineer, of the Environmental Engineering Division (EED), EL.

The authors wish to thank several individuals for their technical assistance in mixing sediment, conducting various tests, and harvesting test specimens. These individuals include contract students Mr. Antoine Bargins, Ms. Heather Holifield, Mr. Johnny McGuffie, Mr. Michael Pendarvis, Ms. Erika Seals, and Ms. Elizabeth Tominey; Ms. Cindy Price of EPED, and Mr. Lawrence Bird of AScI Corporation. Chemical analyses of sediment, water, and tissues were performed by Dr. Eric Crecelius, Battelle/Marine Sciences Laboratory, Sequim, WA. Sediments were collected by Dr. J. A. Word, Mr. J. C. Coley, and Mr. L. D. Antrim, Battelle/Marine Sciences Laboratory, Sequim, WA.

The work was conducted under the supervision of Dr. Bobby L. Folsom, Jr., Chief, Fate and Effects Branch; Mr. Donald L. Robey, Chief, EPED; Dr. Raymond L. Montgomery, Chief, EED; and Dr. John Harrison, Director, EL.

At the time of publication of this report, Dr. Robert W. Whalin was Director of WES. COL Bruce K. Howard, EN, was Commander.

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PART I: INTRODUCTION

Background

The construction of Richmond Harbor and Santa Fe Channel Project were authorized by Congress in 1930. As part of its responsibility for maintaining navigable waterways, the US Army Engineer District, San Francisco plans to deepen Richmond Harbor and Santa Fe Channels located on the northeastern edge of San Francisco Bay in Richmond, California (Figures I-1 and I-2). This work is consistent with US Army Corps of Engineers (USACE) dredging regulations 33 CFR Parts 208 and 220-227, the Clean Water Act 404(b)(1) guidelines, the Ocean Dumping Act and the National Environmental Protection Act (NEPA). Both channels would be deepened to -38 ft mean lower low water (MLLW) from the presently authorized depth of -35 ft MLLW. In addition, a turning basin will be dredged to -38 ft east of Point Potrero and the southwestern junction of Santa Fe and Richmond Harbor Channels will be widened and deepened to -38 ft MLLW. The proposed turning basin and widening area have not been dredged previously. Dredging will produce approximately 1.5 million cubic yards of material that will require disposal.

Sediments were sampled in April 1989 by Battelle Marine/Sciences Laboratory in Sequim, WA to physically and chemically characterize the sediments in both the Santa Fe and Richmond Harbor Channels (Brown, Kohn, Ward and Bjornstad 1989). The sediments from Santa Fe Channel were determined to be unsuitable for unrestricted open water disposal because of the elevated concentrations of DDT found. Therefore, other disposal alternatives, such as upland disposal, would have to be evaluated for these sediments.

The US Army Engineer Waterways Experiment Station (WES) was asked to assist in the evaluation of other alternatives, such as upland disposal, for these sediments. Francingues et al. 1985 and Lee et al. 1991 described the Corps' Management Strategy for Disposal of Dredged Material, in which a sediment is tested and evaluated for potential disposal site environments, including aquatic, wetland and upland. The upland test protocols were used in the present evaluation to determine the potential for migration of contaminants into effluent, surface runoff, and leachates at an upland disposal site.

The Corps management strategy has been applied in total or in part to the following dredging projects:

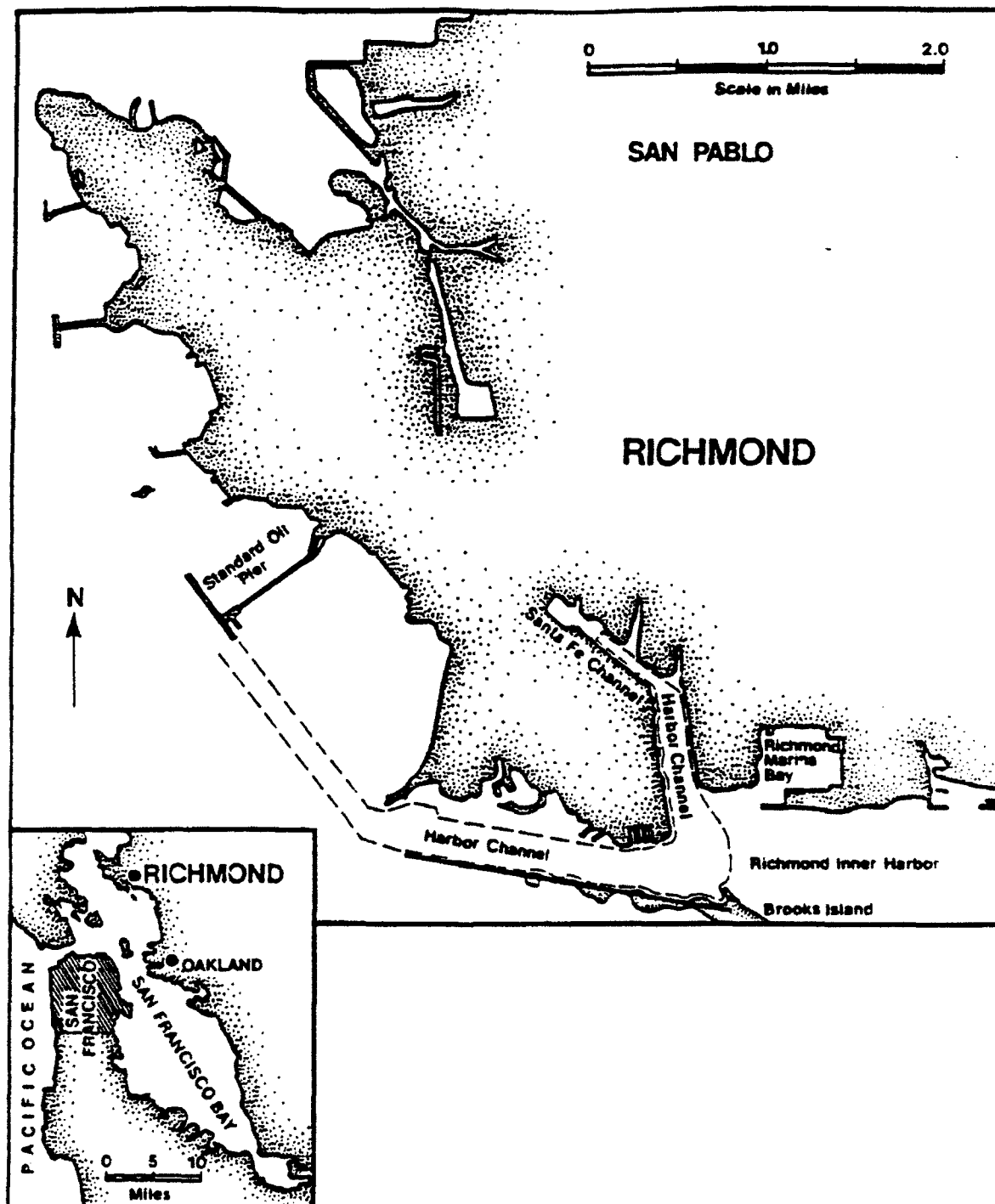


Figure I-1. Location of Richmond Harbor, Richmond, California

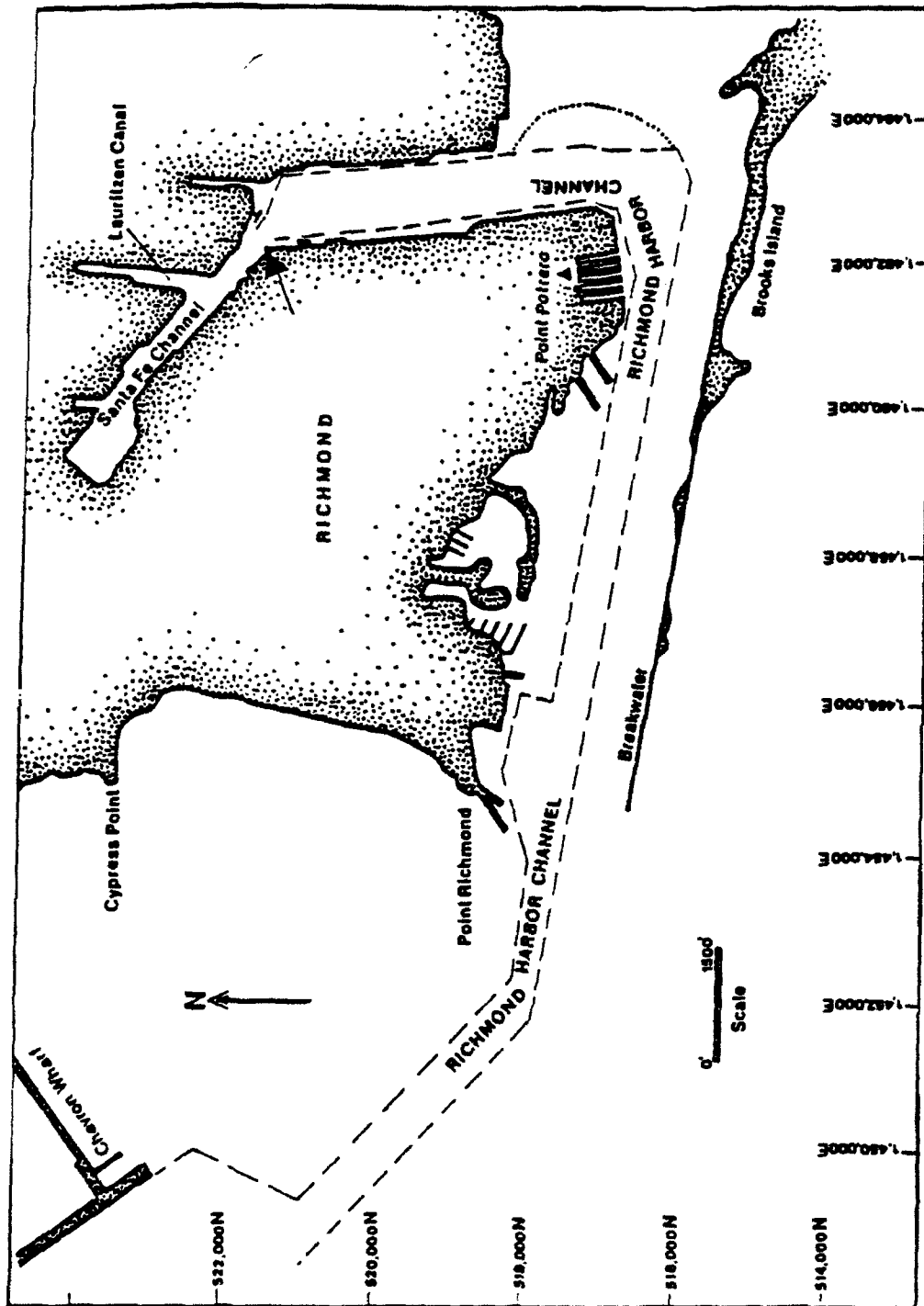


Figure I-2. Location of Santa Fe and Richmond Harbor Channels

Everett Homeport Project, WA
 Black Rock Harbor, CT
 Indiana Harbor, IN
 Blue River Project, Kansas City, MO
 New Bedford Harbor, MA
 Baltimore Harbor, MD
 Southwest Pass, LA
 Corpus Christi Harbor, TX
 Bridgeport Harbor, CT
 Oakland Harbor, CA
 Duwamish Waterway, WA
 Michigan City Harbor, IN
 Detroit River, MI
 Menominee River, WI
 Milwaukee Harbor, WI
 Times Beach CDF Site, Buffalo, NY
 Toledo Harbor CDF, Toledo, OH
 Benton Harbor, MI
 Acid Mine Spoil Restoration, Ottawa, IL
 Dike 12 CDF, Cleveland, OH
 Lock and Dam 2, St. Paul, MN
 Pointe Mouillee, MI
 Broekpolder, Rotterdam, The Netherlands

The Corps management strategy test protocols have also been applied to a number of other contaminated sites such as:

Naval Weapons Station, Concord, CA
 Naval Subbase, Bangor, WA
 PCB Spill Site, Delft, The Netherlands
 Metal Mining Waste Sites, Wales, United Kingdom
 Agricultural Sites, Haren, The Netherlands
 Wetland Sites, Eastern Scheldt, The Netherlands
 Sewage Sludge Amended Soils, Beltsville, MD
 Roadside Contamination Sites, Chicago, IL
 Agricultural Sites, Montepellier, France
 Wetland Sites, Lisbon, Portugal

Test results have been used to evaluate potential contaminant migration and to formulate management strategies and/or remedial actions at these sites.

Purpose and Scope

The purpose of this report is to describe the results of a comprehensive evaluation of the impact of placing Santa Fe Channel sediment in an upland disposal environment. Contaminant migration via effluent, surface runoff, and leachate were evaluated. The upland disposal site would be managed such that plants and animals would not be allowed to colonize the site. Consequently, no upland plant and animal bioassay tests were conducted. Contaminants of

concern were salt, metals, tributyltin (TBT), pesticides (particularly DDT and its derivatives), and polycyclic aromatic hydrocarbons (PAHs).

Test results were interpreted in relation to existing Federal criteria and/or State standards, or existing related data and information from literature and past or present research projects. Because the disposal site is not known, test results of water quality data from filtered water samples were evaluated in relationship to Federal Water Quality Criteria and/or State Water Quality Standards for effluents and receiving waters. Test results were compared to the EPA Acute Water Quality Criteria for the Protection of Aquatic Life (USEPA 1987), and the Effluent and Receiving Water Limitations for Waste Discharge issued by the California Regional Water Quality Control Board (CRWQCB) in response to a permit application by the Port of Oakland for the disposal of Oakland Harbor sediment as levee building material at Twitchell Island in the Sacramento River Delta. In the absence of State Water Quality Standards for an undetermined disposal site, the Federal Water Quality Criteria were assumed to be applicable to give some perspective to test results. Section 401 requires compliance with State Water Quality Standards, rather than Federal Water Quality Criteria. Final effluent limitations will be determined by the state under Section 401 of the Clean Water Act based on the local water quality objectives applicable to the area where the sediment is placed. These laboratory tests give predictions of water quality for specific conditions and should be considered an indication of the potential of an effluent, surface runoff or leachate to meet or exceed applicable water quality standards.

Test data will be discussed in terms of statistical differences. The word statistical is used to describe differences measured at the $P = 0.05$ level of significance using standard statistical procedures that consider variability in test data to separate data means. While some scientists have suggested the use of higher levels of significance such as $P = 0.10$ to imply ecological significance to test data, this was not done in this evaluation. Instead, the words "significant" and/or "substantial" increase or amount was used to describe the magnitude of an increase or amount and will be interpreted in this report to mean that the increase or amount is important ecologically.

PART II: SEDIMENT CHARACTERIZATION

Methods and Materials

Sediment collection, transport, and mixing

Sediment was collected from Santa Fe Channel (Figure II-1) using a vibracoring sampler (See Appendix A for further details). Sediment from core depths to -38 feet was composited into fifteen 55 gallon barrels. All barrels of collected sediments were loaded into a refrigerated truck and transported to the WES for testing. The barrels were placed in a cold storage room at 4 degrees Celsius for 5 days prior to mixing.

Barrels of sediment were removed from the cold storage room and poured into a lined 4x15x4 feet soil bed lysimeter (Figure II-2). The sediment was mixed by hand with shovels and mechanically with a lightning mixer (Figures II-3 and II-4). After mixing, subsamples were randomly collected from the entire soil bed for use in the different test protocols (Figures II-5 and II-6). Mixed sediment samples were containerized and stored in a cold (4 degrees Celsius) storage facility until used (Figures II-7 and II-8). The soil bed was covered for protection prior to initiation of surface runoff tests (Figure II-9).

Sediment mixing was evaluated by collecting aliquot samples from each barrel labelled for each upland test or soil bed after the mixing process. After mixing all barrels of sediment as shown in Figures II-2 through II-6, subsamples of sediment were collected to be used for separate tests of elutriate (EL), surface runoff (SR), and leachate tests (LE). Aliquots of sediment were collected from each container for these tests and analyzed for Cu, %sand, %solids, and total organic carbon (TOC), to evaluate how well the composite sediment was mixed and the uniformity of sediment to be used by the three separate upland tests.

Physical sediment characterization

Sediment samples were tested for engineering properties including liquid limits, plastic limits, void ratio, water content, density, particle size distribution, consolidation and settling, according to procedures described in Engineer Manual 1110-2-5027 (US Army Corps of Engineers 1987).

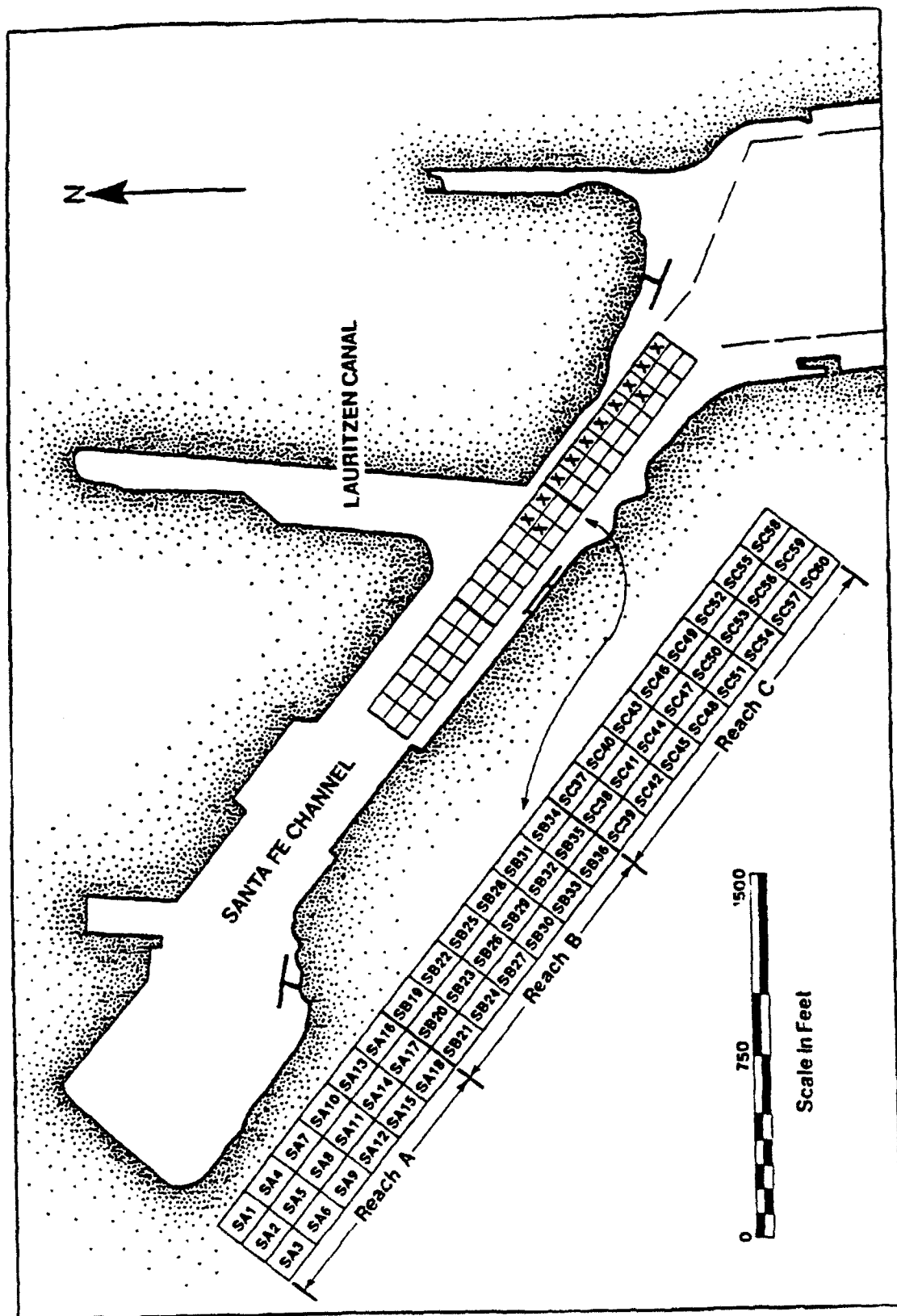


Figure II-1. Location of Sediment Core Sampling Stations in Santa Fe Channel

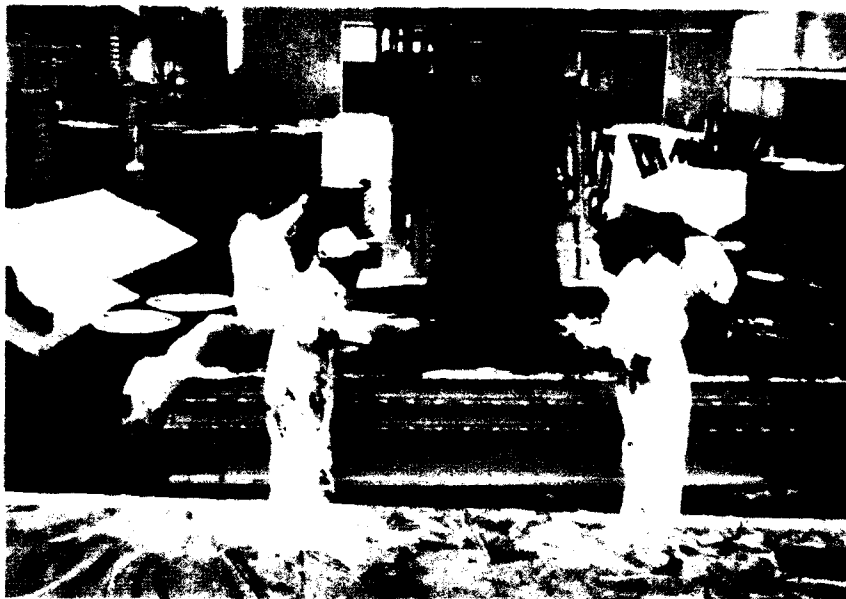


Figure II-2. Barrels Were Emptied Into Soil
Bed Lysimeter For Mixing



Figure II-3. Sediment Was Mixed Manually With
Shovels, Rakes and Hoes



Figure II-4. A Lightning Mixer Was Used To Thoroughly Mix Sediment

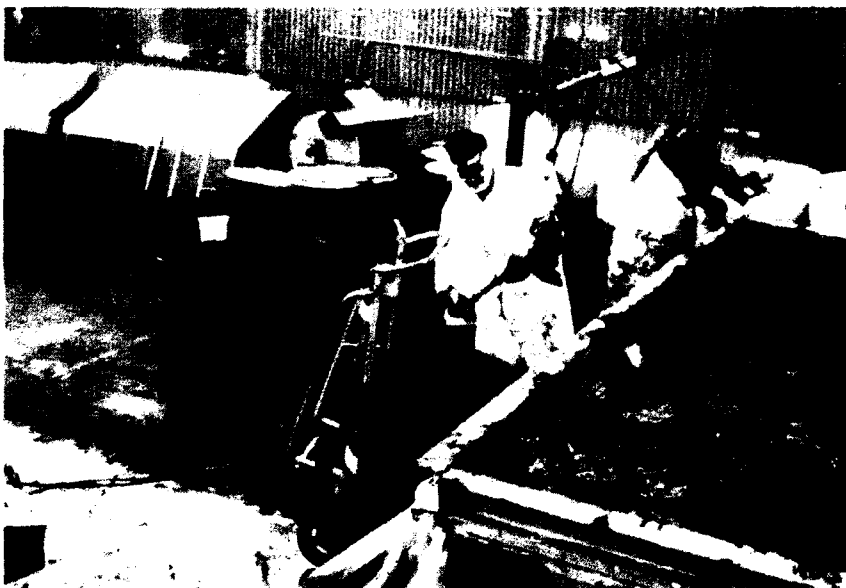


Figure II-5. Random Samples Were Removed From the Soil Bed Lysimeter and Placed in Barrels

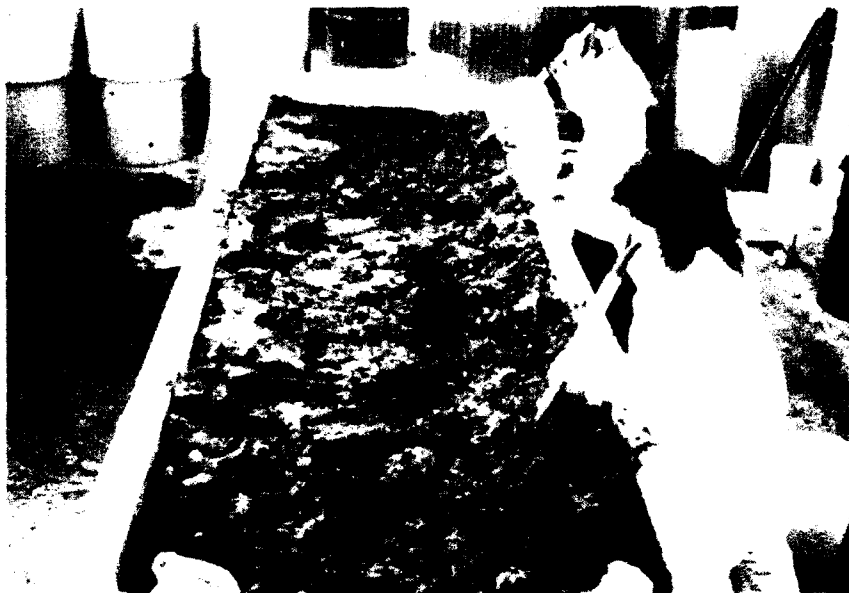


Figure II-6. Additional Samples Were Randomly
Collected From All Sections of the Soil Bed
Lysimeter For Individual Tests



Figure II-7. Mixed Sediments Were Collected in Barrels
and Taken To a Refrigerated Building



Figure II-8. Barrels of Mixed Sediment Were Placed in a Refrigerated Room at 4 Degrees Celsius Until Tested



Figure II-9. Soil Beds Were Covered After Mixing

Sediment and soil chemical characterization

Sediment samples were shipped to Dr. Eric Crecelius at Battelle/Marine Sciences Laboratories, Sequim, WA for the chemical analyses. Analytical methods and references are described in Appendix A. They were similar to the methods discussed in Lee et al. 1992. Santa Fe sediment was analyzed for 10 metals (Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, and Zn), 4 butyltins (tetra, tri, di, and mono), 19 pesticides and 15 polycyclic aromatic hydrocarbons (PAHs). All data received from the analytical laboratory are presented in Appendix A.

Results and Discussion

Adequacy of mixing composite sediment

Sediment mixing was evaluated by collecting aliquot samples from each barrel labelled for each upland test or the soil bed after the mixing process. The coefficients of variation were below 10% in all parameters except TOC which was 39.68 and %sand which was 12.96% for Santa Fe channel sediment (Table II-1). Normally, coefficients of variability of 10% or less are observed in good controlled experimentation. Since TOC values are large numbers (in the thousands) one would expect increased percentages in coefficients of variability. The percent sand coefficient of variability was slightly above 10%.

Table II-1
Variability of Selected Sediment Quality Data After Mixing

<u>Sample</u>	<u>Cu (mg/kg)</u>	<u>TOC (mg/kg)</u>	<u>% Solids</u>	<u>% Sand</u>
RH-LAB-ALG	35.6	5240	66	16.0
RL-LE-ALG	40.8	6670	63	19.0
RH-EL-ALG	43.7	1649	64	16.5
RH-SR-ALG	41.4	6040	62	22.0
MEAN	40.4	4900	64	18.4
STD. DEV.	2.96	1944	1.5	2.38
COEFF. OF VAR.	7.34	39.68	2.32	12.96

Physical sediment characterization

The Santa Fe channel sediment had a sandy clay (CH) texture according to the Unified Soil Classification System. Physical properties are shown in Figure II-10 for the Santa Fe channel sediment. Additional engineering properties for consolidation and settling are included in Appendix A.

Sediment and soil chemical characterization

Results of the chemical analyses of the Santa Fe channel sediment are shown in Tables II-2 (metals), II-3 (metals QA/QC), II-4 (butyltins), II-5 (PAHs), II-6 (PAH method blank values) and II-7 (pesticides).

Bulk chemical analysis data for sediments give an inventory of the presence of contaminants. These data can be compared to bulk chemical analysis data for potential disposal site sediments or soils, and/or to available information or literature that give perspective and/or guidance on acceptable levels of contaminants in soils for specific uses. Two examples of guidance on levels of contaminants in soils are shown in Tables II-8 and II-9. Another example of bulk chemical analysis data that could be used for comparison is soil data from Twitchell Island, a potential disposal site of levee rehabilitation (Lee et al. 1992). These comparisons will indicate whether the dredged material contains concentrations of contaminants lower than, equal to, or higher than the respective referenced data and will indicate whether there is reason to believe the dredged material is contaminated and there is a need for further testing.

Santa Fe channel sediment metals are shown in Table II-2 with the metal concentrations found in Twitchell Island soils and levee soils, collected from Twitchell Island. A few of these metals were elevated in comparison to the Twitchell Island soil but none are unusually high for sediments (Tatem 1990). Holnigren et al. 1987 described allowable application rates for five metals, Cd, Cu, Ni, Pb, and Zn. None of the metals in the Santa Fe sediment exceed these allowed application rates although nickel concentrations appear to be at the maximum concentration allowed for agricultural production. Hegberg et al. 1991 lists soil phytotoxic concentrations for metals. The only Santa Fe channel sediments metal to exceed this list is Cr, and again the levels are not unusual when compared to other soils (Engler 1980, Richard and Chadsey 1990). All sediments contain metals and it is normal for the concentrations to vary from site to site. Unless a metal is found to be very high in comparison to reference or disposal site soils or known phytotoxic concentrations, one of the best ways to evaluate them is to conduct laboratory studies such as the

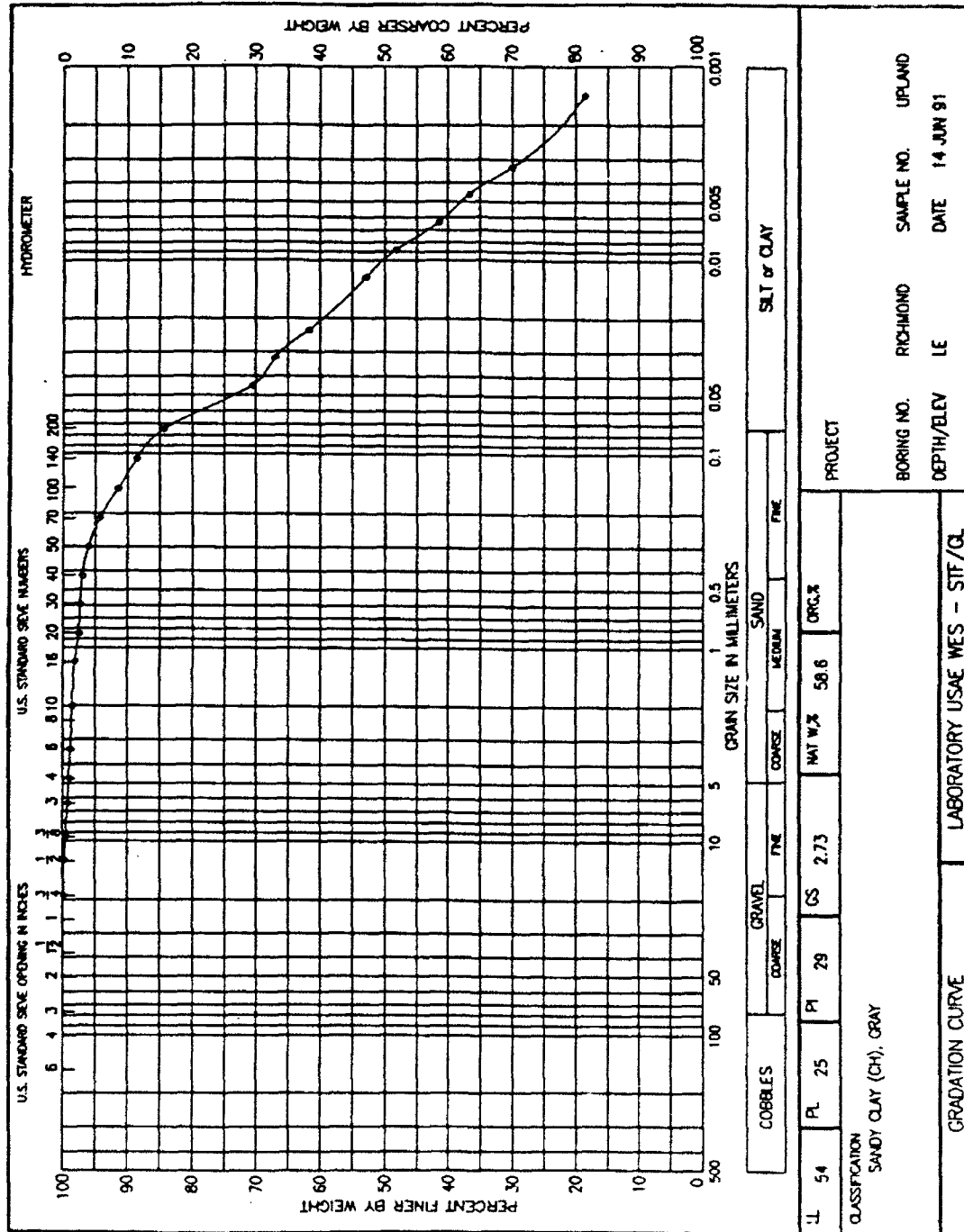


Figure II-10. Physical Engineering Properties of Santa Fe Channel Sediment

Table II-2
Mean Concentrations of Metals in Santa Fe Channel Sediment
and Twitchell Island Soil

<u>Parameter</u>	<u>Concentrations (mg/kg dry weight)</u>		
	<u>Santa Fe Channel</u>	<u>Twitchell Island*</u>	<u>Levee Soils*</u>
Silver/Ag	0.258 (.010)**	0.14	--
Arsenic/As	8.450 (0.95)	14.7	9.3
Cadmium/Cd	0.698 (.029)	0.46	3.4
Chromium/Cr	186.3 (4.65)	129.0	43.8
Copper/Cu	56.38 (6.73)	41.0	29.0
Mercury/Hg	0.293 (.019)	0.21	0.214
Nickel/Ni	80.75 (3.59)	73.0	39.9
Lead/Pb	29.10 (1.26)	13.0	10.8
Selenium/Se	0.175 (.040)	--	0.07
Zinc/Zn	117.0 (5.35)	96.0	59.3

* Data for Twitchell Is. and Levee soils are from Lee et al. 1992.

** Values shown in parentheses are standard deviations.

effluent, leachate, and runoff tests. Santa Fe Channel sediment metal concentrations are in the range of those found in normal agricultural soils (Table II-9) with the exception of nickel. Santa Fe channel sediment appears to be elevated in Ni, Cd, Cr, Cu, Pb, and Zn compared to natural soils or reference sediments but only Cr concentrations exceed published phytotoxic metal concentrations (Hegberg et al. 1991). Table II-3 shows some metal QA/QC data from analytical laboratory.

Table II-3
Concentrations of Metals in a Standard Reference Material
Analyzed By the Analytical Laboratory - Battelle/
Marine Sciences Laboratories

<u>Parameter</u>	<u>Concentrations (mg/kg dry weight)</u>	
	<u>OW - S</u>	<u>SRM - Certified Value</u>
Silver/Ag	0.09	NA*
Arsenic/As	11.0	11.6
Cadmium/Cd	0.32	0.36
Chromium/Cr	68.0	76.0
Copper/Cu	20.1	18.0
Mercury/Hg	0.078	0.063
Nickel/Ni	34.3	32.0
Lead/Pb	26.8	28.2
Selenium/Se	0.54	(0.6)**
Zinc/Zn	131.3	138.0

* NA - Not Analyzed.

** Values in parentheses are not certified.

Table II-4
Mean Concentrations of Butyltins in Santa Fe Channel Sediment
and Twitchell Island Soil

<u>Parameter</u>	<u>Concentrations (ug/kg dry weight)</u>	
	<u>Santa Fe Channel</u>	<u>Twitchell Island*</u>
<u>Butyltin</u>		
Tetra	<0.8	--
Tri	6.35 (0.84)**	<2.0
Di	5.98 (0.78)	<2.0
Mono	2.00 (0.42)	<2.0
TOTAL	15.13	

* Data for Twitchell Is. are from Lee et al. 1992.

** Values shown in parentheses are standard deviations.

Table II-5
Mean Concentrations of PAHs in Santa Fe Channel Sediment and
Twitchell Island Soil

Parameter PAH	Concentrations (ug/kg dry weight)	
	Santa Fe Channel	Twitchell Island*
Naphthalene	<24.3	<20
Acenaphthylene	4.13	<20
Acenaphthene	<9.2	<20
Fluorene	9.90	<20
Phenanthrene	62.2	50
Anthracene	38.5	<20
Fluoranthene	105.1	260
Pyrene	196.8	320
Benzo(a)anthracene	144.8	70
Chrysene	158.8	120
Benzofluoranthene**	625.6	250
Benzo(a)pyrene	311.1	180
Indeno(1,2,3-c,d)pyrene	183.0	180
Dibenzo(a,h)anthracene	41.4	20
Benzo(g,h,i)perylene	<u>229.6</u>	<u>210</u>
TOTALS	2144.6	1760
Mean % Sur Rec Anthracene	90.8	

* Data for Twitchell Island are from Lee et al. 1992.

** All benzofluoranthene isomers (b,j and k) are quantified together.

Table II-4 shows the Santa Fe channel sediment butyltin data. The data show this sediment contains approximately 15 ppb total butyltins, a concentration that is greater than that found for Twitchell soil. There are few specific guidelines for evaluating butyltins in sediment. Therefore potential environmental effects were tested using laboratory tests such as the effluent, leachate, and runoff tests described by Lee et al. 1992.

Data for Santa Fe channel sediment and Twitchell Island soil PAHs are presented in Table II-5. All but two of the PAH compounds were detected in this sediment and some appear to be at concentrations greater than those of

Table II-6

PAH Method Blank Values for Santa Fe Channel Sediment

Parameter PAH	Concentrations (ug/kg dry weight) Santa Fe Channel
Naphthalene	<1.50
Acenaphthylene	<0.22
Acenaphthene	<0.56
Fluorene	<0.44
Phenanthrene	<0.59
Anthracene	<0.26
Fluoranthene	<0.37
Pyrene	<0.28
Benzo(a)anthracene	<0.26
Chrysene	<0.22
Benzofluoranthene	<0.28
Benzo(a)pyrene	<0.22
Indeno(1,2,3-c,d)pyrene	<0.35
Dibenzo(a,h)anthracene	<0.20
Benzo(g,h,i)perylene	<0.18

the Twitchell Island soil. There are few guidelines for sediment PAHs but Tatem 1990 listed several reference sediments which did not contain detectable levels of PAHs. Typical contaminated sediments may contain 25,000 ppb total PAHs, a concentration approximately 12 times higher than Santa Fe channel sediment. The Santa Fe channel sediment (Table II-5) contains only 105 ppb fluoranthene but does contain other PAHs; consequently, there is a reason to believe the sediment may be contaminated and further testing is warranted. Table II-6 contains PAH method blank values. Data for Santa Fe channel sediment pesticides show (Table II-7) DDD, DDT and dieldrin concentrations both greater than detection limits and above the method blank values. Endrin and endrin ketone were also found but at very low ppb levels. The Twitchell Island soil contains DDT but at concentrations much less than those shown for Santa Fe channel sediment. There are few guidelines for potentially harmful levels of sediment pesticides. However, these contaminants are frequently absent or below detection limits in most reference sediments (Tatem 1990).

Table II-7

Mean Concentrations of Pesticides in Santa Fe Channel Sediment and
Twitchell Island Soil

<u>Parameter</u>	<u>Concentrations (ug/kg dry weight)</u>			<u>Method Blank</u>
	<u>Santa Fe Channel</u>	<u>Twitchell Island*</u>	<u>Levee Soils*</u>	
Aldrin	<3.4	<1	--	<2
A - BHC	<3.4	<1	--	<2
B - BHC	<3.4	<1	--	<2
D - BHC	<3.4	<1	--	<2
Chlordane	<3.4	<1	--	<2
4,4-DDD	202.5 (39.5)	<3	--	<2
4,4-DDE	<3.4	2.6	3.8	<2
4,4-DDT	185.5 (70.5)	5.8	7.3	9.2
Dieldrin	20.38 (24.4)	<1.5	--	5.1
Endosulfan I	<3.4	<1	--	<2
Endosulfan II	<3.4	<1.5	--	<2
Endosulfan Sulfate	<3.4	<3	--	<2
Endrin	4.90 (3.40)	<1.5	--	6.5
Endrin Aldehyde	3.70 (1.01)	<1.5	--	13.0
Heptachlor	<3.4	<1	--	<2
Heptachlor Epoxide	<3.4	<1	--	<2
Lindane (G - BHC)	<3.4	<1	--	<2
Toxaphene	<34	<150	--	<2
Methoxychlor	<6.7	<4	--	<2
Endrin Ketone	3.75 (1.11)	<1.5	--	<2

* Data for Twitchell Is. and Levee soils are from Lee et al. 1992.
() Standard deviation.

Table II-8
Other Possible Metal Reference Comparisons

	<u>Tatem 1990 Mean Reference Sediment Values</u>	<u>Richard and Chadsey 1990 Natural Average</u>	<u>Hegberg et al. 1991 Phytotoxic Concentration</u>
Ag	1.1	--	2.0
As	4.9	--	28.0
Cd	0.8	0.1	5.0
Cr	40.0	100.0	94.0
Cu	21.0	30.0	98.0
Hg	0.3	--	3.0
Ni	17.2	40.0	100.0
Pb	32.0	10.0	180.0
Se	0.9	--	9.0
Zn	68.0	50.0	270.0

Table II-9
Background Levels and Allowable Applications of Several
Heavy Metals for US Cropland Soils*

<u>Parameter</u>	<u>Background Concentration in Surface Soils, mg/kg</u>			<u>No Effect Allowed Addition** kg/ha</u>	<u>Median Plus Allowed Application mg/kg</u>
	<u>5 percentile</u>	<u>median</u>	<u>95 percentile</u>		
Lead	4.0	11	27	1,000	511
Zinc	7.3	54	129	500	304
Copper	3.7	19	96	250	144
Nickel	3.8	19	59	125	82
Cadmium	0.035	0.20	0.78	5	2.7
pH	4.6	6.1	8.1	--	--

* Holnigren et al. (1987).

** Allowed application is mixed into the 0-15 cm (0-6 in.) surface layer of soil.

PART III: EFFLUENT TEST

Methods and Materials

Applicability of test procedures

The prediction of effluent water quality from upland disposal sites is one of the evaluations described by Francingues et al. 1985 for the management of dredged material. The interpretation of the test data was generally described in the decision-making framework of Peddicord et al. 1986 and Lee et al. 1991. The term effluent is normally used to describe the water discharged from a confined (diked) area during hydraulic placement of dredged material. Under these conditions a pond of water is maintained within the diked area, and the volumetric flowrate of effluent is approximately equal to the volumetric inflow rate.

For the disposal operation as described for the Santa Fe channel project both hydraulic filling and mechanical filling alternatives are possible. Therefore, the conditions for "effluent" discharge may be much different if the material will be mechanically dredged, transported to the disposal site by barge, removed directly from the barge with a clamshell, and mechanically placed in a upland confined disposal site. These operations will result in minimal entrainment of excess water as compared to a hydraulic placement operation.

There is no standardized testing procedure for prediction of the quality of water discharged during confined placement of dredged material on land by mechanical equipment as described above. However, modified elutriate procedures have been developed for prediction of the quality of effluent discharged from confined disposal areas during hydraulic placement (Palermo 1985). A schematic of the modified elutriate procedure is shown in Figure III-1. These tests are designed to estimate both dissolved and particle-associated contaminant concentrations in the effluent. The modified elutriate test is considered a conservative estimate of contaminant release for material placed by mechanical means, therefore, these procedures were used to estimate the quality of effluent discharged from the confined mechanical placement.

The use of modified elutriate procedures for this case is considered conservative worst case for several reasons. The test procedures simulate the complete mixing of sediment and water during hydraulic dredging processes and would result in more potential contaminant release to water that would occur



Figure III-1. Glass Columns of Sediment/Water
Elutriate Mixture

with mechanical dredging and placement. Also, the procedure calls for extraction of a sample for analysis after a settling period of 24 hours. Such a procedure would result in a higher concentration of particle-associated contaminants than would be expected for water release from a mechanically placed material because only the finer particle fractions remain after a 24 hour settling period, while for mechanical effluent, some of all particle fractions would be "washed" from the sediment mass during water loss.

Procedures

Modified elutriate tests were conducted on the Santa Fe Channel sediment samples using procedures described in Palermo (1985). Replicates of the elutriate tests were conducted using the composite sediment samples and water samples collected as described in Part II of this report. The elutriate test procedures were conducted by Dr. Henry Tatem at WES. Analysis of physico-chemical parameters in the elutriate such as total suspended solids (TSS), pH, dissolved oxygen (DO), and conductivity and salinity was performed by the WES Analytical Laboratory Group (ALG). Subsamples of the elutriate were preserved and transported to Battelle for analysis of metals, PAHs and tri-, di-, and mono-butyltins. Both dissolved and total concentrations of contaminants in the modified elutriate were determined. Because of the need for large samples

for chemical analysis, multiple test runs were conducted. TSS concentrations were not determined for the elutriate samples used for chemical analysis, but were determined using separate elutriate test runs.

Data were analyzed using the computer program EFQUAL which is designed for reduction and analysis of modified elutriate data and prediction of effluent quality from confined disposal areas. EFQUAL calculates predicted values for both dissolved and total effluent contaminant concentrations and determines required effluent dilutions for those parameters exceeding given criteria or standards. EFQUAL is a part of the Automated Dredging and Disposal Alternatives Management System (Schroeder and Palermo 1990).

Results and Discussion

The replicate mean results for dissolved contaminants in the modified elutriate tests are summarized in Table III-1 for the Santa Fe Channel sediment. For those replicates for which the elutriate samples were below detection, the detection limit was used in calculating the mean values.

The dissolved and total modified elutriate concentrations were used to calculate fractions of the contaminants associated with the suspended particles as described in Palermo (1985). These fractions were then used to estimate a total concentration of contaminants in the effluent for a range of assumed effluent TSS concentrations from 50 to 200 mg/l. These results are shown in Table III-2. The total modified elutriate concentrations were equal to or lower than concentrations for the dissolved samples for some test replicates. In this case, the TSS fraction did not contribute to the total concentrations.

Water quality standards

The estimated dissolved concentrations in the effluent are equal to the dissolved modified elutriate test concentrations as shown in Table III-2. For this analysis, the dissolved effluent concentrations were compared to the EPA Fresh and Marine Acute Water Quality Criteria for the Protection of Aquatic Life (USEPA 1987), as well as the Effluent and Receiving Water Limitation standards for dredging Oakland Harbor issued by CRWQCB in response to a permit application by the Port of Oakland. The latter was done to give more perspective to test results. In the absence of state water quality standards for an undetermined disposal site, the federal water quality criteria were assumed to be applicable to give some perspective to test results. Section 401 requires

Table III-1

Modified Elutriate Results for Santa Fe Channel Composite Sample

<u>Parameter</u>	<u>Elutriate Dissolved ug/l</u>	<u>Ca State RWQCB Limitations</u>	<u>Freshwater* EPA Acute WQ Criteria ug/l</u>	<u>Saltwater* EPA Acute WQ Criteria ug/l</u>
Silver	0		4.1	2.3
Arsenic	3.37			
Cadmium	0.8	1.8	3.9	43
Chromium	1.44	16	16	1100
Copper	4.9167	9.2	18	2.9
Mercury	0.0397		2.4	2.1
Nickel	1.1967		1400	75
Lead	2.2167	34	82	140
Selenium	bd		260	410
Zinc	28.5667	65	120	95
Tributyltin	0.0144	0.08		
Dibutyltin	0.0121			
Monobutyltin	0.0092			
Conductivity				
pH	7.4			
DO	9			
Salinity	29			
Naphthalene	0.0376		2300	2350
Acenaphthylene	0.0057			
Acenaphthene	0.0143		1700	970
Fluorene	0.0114		0	0
Phenanthrene	0.0152			
Anthracene	0.0067			
Fluoranthene	0.0095		3980	40
Pyrene	0.0071			
Benzo[a]anthracene	0.0067			
Chrysene	0.0057			
Benzo[k]fluoranthene	0.0071			
Benzo[b]fluoranthene	0.0071			
Benzo[a]pyrene	0.0057			
Indeno[1,2,3-c,d]pyrene	0.0091			
Dibenzo[a,h]anthracene	0.0052			
Benzo[g,h,i]perylene	0.0046			

* In the absence of state water quality standards for an undetermined disposal site, the Federal Water Quality Criteria were assumed to be applicable to give perspective to test results.

Table III-2

Predicted Effluent Total Concentrations for Santa Fe Channel Sediment

Parameter	Predicted Total Effluent Concentrations in ug/l for Effluent TSS Concentrations			
	50 mg/l	100 mg/l	150 mg/l	200 mg/l
Silver	0.0100	0.010	0.010	0.010
Arsenic	3.1600	3.300	3.470	3.640
Cadmium	0.8000	0.800	0.800	0.800
Chromium	1.8300	2.2300	2.6200	3.0200
Copper	4.9100	4.9100	4.9100	4.910
Mercury	0.0397	0.0397	0.0397	0.0397
Nickel	1.88	2.56	3.25	3.93
Lead	2.300	2.410	2.490	2.580
Selenium	bd*	bd	bd	bd
Zinc	28.560	28.560	28.560	28.560
Tributyltin	0.0148	0.0152	0.0156	0.0160
Dibutyltin	0.0121	0.0121	0.0121	0.0121
Monobutyltin	0.0092	0.0092	0.0092	0.0092
Naphthalene	0.0383	0.0391	0.0398	0.0406
Acenaphthylene	0.0058	0.0060	0.0061	0.0062
Acenaphthene	0.0225	0.0307	0.0389	0.0471
Fluorene	0.0116	0.0119	0.0121	0.0123
Phenanthrene	0.0155	0.0158	0.0161	0.0165
Anthracene	0.0068	0.0069	0.0070	0.0071
Fluoranthene	0.0097	0.0099	0.0101	0.0103
Pyrene	0.0127	0.0182	0.0238	0.0294
Benzo[a]anthracene	0.0068	0.0069	0.0070	0.0071
Chrysene	0.0060	0.0062	0.0065	0.0068
Benzo[k]fluoranthene	0.0073	0.0074	0.0075	0.0076
Benzo[b]fluoranthene	0.0073	0.0074	0.0075	0.0076
Benzo[a]pyrene	0.0058	0.0060	0.0061	0.0062
Indeno[1,2,3-c,d]pyrene	0.0093	0.0094	0.0096	0.0097
Dibenzo[a,h]anthracene	0.0068	0.0055	0.0056	0.0057
Benzo[g,h,i]perylene	0.0047	0.0048	0.0048	0.0049

* Below detection.

compliance with State water quality standards, rather than Federal water quality criteria.

EFQUAL uses t-tests to compare the predicted effluent concentrations to specified criteria or standards. Contaminant concentrations less than or equal to the assumed criteria are postulated as the null hypothesis. Contaminant concentrations greater than the assumed criteria serve as the alternate hypothesis. A rejection of the null hypothesis suggests values were greater than the assumed criteria. In general, the predicted dissolved effluent

concentrations were well below all assumed criteria and standards. An exception was copper that exceeded the EPA saltwater criterion (level of confidence of 98%). A dilution in the mixing zone of less than 2 would be required to meet the assumed criterion.

Mass release

No standards for mass loading were specified by the Water Quality Control Board. Therefore, predictions of the total concentration of contaminants in the effluent for an assumed range of effluent TSS from 50 to 200 mg/l were used to estimate potential mass releases. These results are shown in Tables III-2. These estimates of total concentrations were used to compute a mass release of contaminants expressed as a percentage for an assumed hydraulic placement operation.

The sediment contaminant concentrations for the Santa Fe samples were used as the initial contaminant concentrations as placed (shown in Table III-3). Hydraulic placement was assumed to result in an inflow suspended solids concentration of 150 g/l. The total effluent concentrations of contaminants for the assumed range of 50 to 200 mg/l of effluent TSS was then used to compute the percentage of total contaminants placed which would be discharged as effluent. Mass release calculated for the hydraulic placement method is conservative (worst case) as compared with that for mechanical placement. The resulting mass release expressed as percentage of the total contaminants placed are summarized in Table III-3.

The mass releases were generally well below one percent. The butyltin releases for Santa Fe channel sediment was higher ranging up to 3 percent. These higher values of release expressed as a percentage reflect the fact the initial concentrations of butyltins in the sediments were comparatively low and all release is associated with the dissolved fraction. These data generally indicate that the placement operation should be managed to reduce the level of suspended solids in the effluent to the greatest degree practical.

Biological Evaluation

The modified elutriate test procedure is discussed by Palermo (1986). It is used to predict both dissolved and particle-associated concentrations of environmental contaminants in effluents from confined dredged material disposal areas. One important difference between the standard elutriate developed by the CE (EPA/CE 1977) and the modified elutriate is the method used to

Table III-3

Estimated Mass Release for Santa Fe Channel Sediment

Parameter	Sediment Concentration mg/kg	Predicted Percentage Mass Loss for Effluent TSS Concentration			
		50 mg/l	100 mg/l	150 mg/l	200 mg/l
Silver	0.258	0.03	0.03	0.03	0.03
Arsenic	8.5	0.25	0.26	0.27	0.29
Cadmium	0.69	0.77	0.77	0.77	0.77
Chromium	186	0.01	0.01	0.01	0.01
Copper	56.3	0.06	0.06	0.06	0.06
Mercury	0.218	0.12	0.12	0.12	0.12
Nickel	81	0.02	0.02	0.03	0.03
Lead	29.1	0.05	0.06	0.06	0.06
Selenium	0.17	0	0	0	0
Zinc	117	0.16	0.16	0.16	0.16
Tributyltin	0.00635	1.55	1.60	1.64	1.68
Dibutyltin	0.00598	1.35	1.35	1.35	1.35
Monobutyltin	0.002	3.07	3.07	3.07	3.07
Naphthalene	0.0243	1.05	1.07	1.09	1.11
Acenaphthylene	0.00413	0.94	0.97	0.98	1.00
Acenaphthene	0.0092	1.63	2.22	2.82	13.41
Fluorene	0.0099	0.78	0.80	0.81	0.83
Phenanthrene	0.06218	0.17	0.17	0.17	0.18
Anthracene	0.03853	0.12	0.12	0.12	0.12
Fluoranthene	0.105	0.06	0.06	0.06	0.07
Pyrene	0.196	0.04	0.06	0.08	0.10
Benzo[a]anthracene	0.144	0.03	0.03	0.03	0.03
Chrysene	0.158	0.03	0.03	0.03	0.03
Benzo[k]fluoranthene	0.625	0.01	0.01	0.01	0.01
Benzo[b]fluoranthene	0.625	0.01	0.01	0.01	0.01
Benzo[a]pyrene	0.311	0.01	0.01	0.01	0.01
Indeno[1,2,3-c,d]pyrene	0.182	0.03	0.03	0.04	0.04
Dibenzo[a,h]anthracene	0.0414	0.11	0.09	0.09	0.09
Benzo[g,h,i]perylene	0.229	0.01	0.01	0.01	0.01

determine the volume of sediment to be mixed with the water. The modified elutriate generally is prepared using more sediment than the standard elutriate. Both elutriates were originally developed for use as chemical samples but now are being used as well for various bioassay testing. This report presents both chemical and biological data on modified elutriate prepared from the Santa Fe Channel sediment. This kind of comprehensive analysis has not been attempted in the past.

Modified elutriates were prepared following procedures outlined in Palermo (1985) and (1986). Step one was to determine the grams of dry Santa Fe Channel sediment in a known volume (grams per liter). This value was then used in the equations described in Palermo (1985), assuming a slurry concentration of 150 grams per liter. Sediment and site water were well mixed in a gallon jar prior to being agitated vigorously in a 4-liter cylinder for 1 hour by aeration. After being allowed to settle for 24 hours the supernatant was collected from the cylinder by siphoning. A large volume of elutriate was needed for the chemical analyses, both filtered and unfiltered samples, and the bioassays. Each cylinder produced approximately 1.8 to 2.2 liters of modified elutriate. Approximately 12 liters of water were siphoned from the 5 cylinders and placed in gallon jars. In some cases, the modified elutriates were held overnight at 4 degrees C, while beakers and animals were being prepared. There was no sediment layer present in these samples. These samples were sent for chemical analyses of metals, butyltins and PAHs. The chemistry laboratory wanted as much as 3 liters of samples (6 liters counting both filtered and unfiltered samples) for each of the two organic parameters and about 1 liter for the metals. Additional water was required for the bioassays. The procedure for preparation of these samples was to take the contents of two or three cylinders to make one chemical sample, both filtered and unfiltered. Additional modified elutriate runs were completed for the bioassays. The bioassays were performed on composite samples of modified elutriate from all five cylinders. Separate modified elutriates were made, using similar sediment/water concentrations, for the total suspended solids calculations needed to predict the size of the disposal area needed.

Results and Discussion

Table III-4 shows results from the modified elutriate bioassay. These modified elutriates were always at a salinity of 25-28 ppt because they were made with dredging site water. The modified elutriate settled to 3 distinct layers, a 2-3 cm sandy layer, a lighter 12 cm sediment layer and the relatively clear water layer. The dissolved oxygen of the modified elutriates was always greater than 7 to 8 ppm; pH was 7.7 - 7.9, similar to laboratory culture water of the same salinity. Neomysis exposed to the Santa Fe channel sediment modified elutriate demonstrated no toxicity. Therefore it is concluded that effluent from disposal of the Santa Fe channel sediment in an

Table III-4
Percent Survival of Neomysis Exposed to Santa Fe
Channel Sediment Modified Elutriate for
96 hours at 25 ppt salinity

<u>Treatment</u>		<u>Percent survival</u>
Controls	1 -	100
	2 -	100
	3 -	100
	4 -	100
	5 -	90
10 %	1 -	100
	2 -	100
	3 -	100
	4 -	100
	5 -	100
50%	1 -	100
	2 -	100
	3 -	100
	4 -	100
	5 -	90
100%	1 -	100
	2 -	100
	3 -	100
	4 -	90
	5 -	100
Site Water	1 -	100
	2 -	100
	3 -	90
	4 -	100
	5 -	100

upland CDF will have very little potential for adversely affecting marine aquatic organisms in the receiving water.

Effluent Impacts and Controls

This evaluation of the effluent indicated that, with the exception of copper for the Santa Fe channel sediment, the effluent will meet all assumed water quality criteria and standards prior to any mixing. The concentrations of dissolved copper for Santa Fe exceeding the assumed criteria will require a

dilution of up to 2 in the mixing zone to meet the assumed criterion. This degree of mixing can generally be achieved within a short distance of the effluent discharge.

The total mass release of contaminants as effluent was estimated to be generally less than three percent of the total contaminants placed, and varied with respect to the assumed concentration of TSS in the effluent. The placement operation should be managed to reduce the TSS concentration in the effluent to the largest degree practical. This can be accomplished by ponding of effluent water within the confined disposal site prior to discharge. The resulting sedimentation of suspended solids should reduce the total mass release of contaminants.

The salinity of the effluent could potentially cause some adverse environmental impacts. A dilution of approximately 10 to 1 would reduce the salinity to less than 2 ppt and would minimize any impacts due salinity.

PART IV: SURFACE RUNOFF TEST

Chemical Evaluation

Sediments removed from waterways by construction projects sometime contain elevated concentrations of contaminants such as heavy metals, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs). The potential for adverse environmental impacts from contaminants carried by surface runoff depends on several factors including the chemical form of the contaminants and the type of disposal environment. Wet, unoxidized dredged material usually has a $\text{pH} \geq 7$ with most contaminants tightly bound to the sediment particulates. Movement of contaminants from the disposal site by surface runoff would result primarily from erosion of sediment (Skogerboe et al. 1987). Suspended solids concentrations in surface runoff could range from 5,000 to 50,000 mg/l. Unfiltered (total) contaminant concentrations in surface runoff could also be very high, while filtered (dissolved) contaminant concentrations would be relatively low. When the dredged material is placed in an upland disposal environment, physicochemical changes occur as the material dries and oxidizes. These changes may significantly affect the surface runoff water quality, particularly the filtered contaminant concentrations. As the sediment dries and oxidizes a hard surface crust forms which makes the sediment more resistant to erosion and decreases suspended solids to 10 to 1,000 mg/l. Unfiltered contaminant concentrations will decrease by several orders of magnitude, but filtered concentrations of some contaminants may increase. When the filtered concentration statistically equals the unfiltered concentration, most of the contaminant is dissolved rather than adsorbed to particulates (Skogerboe et al. 1987).

The prediction of surface runoff water quality from Corps of Engineers (CE) upland disposal sites is one of the evaluations described by Francingues et al. (1985) for the management of dredged material. The interpretation of the test data has been generally described in the decision-making framework of Peddicord et al. (1986) and Lee et al. (1991). The US Army Engineer Waterways Experiment Station (WES) developed a rainfall simulator, lysimeter system to predict surface runoff water quality from CE project sites. The WES system is a rotating disk type rainfall simulator modified from a design of Morin, Goldberg, and Seginer (1967). It incorporates the latest methods to accurately duplicate the drop size and terminal velocities of natural rainfall, factors

which are critical in erosion and infiltration studies (Westerdahl and Skogerboe 1982). Extensive field verification studies have been conducted with the WES Rainfall Simulator, Lysimeter System on a wide range of CE project sites (Westerdahl and Skogerboe 1982; Lee and Skogerboe 1984; Skogerboe et al. 1987). The WES Rainfall Simulator/Lysimeter System proved to be an effective tool for predicting surface runoff rates, soil loss, and contaminant concentrations. This study was designed to predict potential surface runoff water quality from upland disposal of dredged material contaminated with heavy metals, PAHs, and butyltins from the Santa Fe Channel sediment. Sediment was collected from the proposed dredging site and tested using the WES Rainfall Simulator/ Lysimeter System. Surface runoff water quality tests were conducted on the wet, unoxidized sediment and again, six months later on air-dried and oxidized sediment. Runoff samples were analyzed for suspended solids, pH, conductivity, and contaminants.

Test results were interpreted in relation to existing Federal criteria and/or State standards, or existing related data and information from literature and past or present research projects. Normally, test results of water quality data from filtered water samples were evaluated in relationship to Federal water quality criteria and/or State water quality standards for effluents and receiving waters. Test results were compared to the EPA Acute Water Quality Criteria for the Protection of Aquatic Life (USEPA 1987), and the Effluent and Receiving Water Limitations for Waste Discharge issued by the California Regional Water Quality Control Board (CRWQCB) in response to a permit application by the Port of Oakland for the disposal of Oakland Harbor sediment as levee building material in the Sacramento River Delta. While these limitations may only apply to sediments from Oakland Harbor, they do give some perspective to the implication of potential impact on water quality should such limitations be issued for the Santa Fe Channel sediments. In the absence of State Water Quality Standards for an undetermined disposal site, the federal water quality criteria were assumed to be applicable to give some perspective to test results. Section 401 requires compliance with State water quality standards, rather than Federal water quality criteria. Final effluent limitations will be determined based on the local water quality objectives applicable to the area where the sediment is placed. These laboratory tests give predictions of water quality for specific conditions and should be considered an indication of the potential of an effluent, surface runoff or leachate to meet or exceed applicable water quality standards.

Methods and Materials

One soil bed lysimeter (4.57 m by 1.22 m) was filled to a depth of 0.33 m with sediment from the Santa Fe Channel. After thorough mixing, standing water on the sediment was decanted off the surface of the lysimeter. A composite sediment sample was collected from each lysimeter and analyzed for pH, electrical conductivity, arsenic, cadmium, chromium, copper, lead, mercury, zinc, tributyltin, dibutyltin, and monobutyltin, pesticides, PAHs and PCBs (USEPA 1986). Each sediment was then tested with the W&S rainfall simulator using three, 30-min storm events at 5.08-cm/hr on successive days (Figures IV-1, IV-2, IV-3), Skogerboe et al. 1987). Runoff rates were measured every minute, and 4-liter samples were collected for chemical analysis at 5, 15, and 25 min after the runoff began to occur. Additional samples were collected for suspended solids determinations at several additional points along the surface runoff hydrograph. The 4-liter samples were combined into a composite sample for each test run and analyzed chemically for filtered and unfiltered heavy metals, butyltins, pesticides, PAHs and PCBs (USEPA 1984). Bioassay tests were also conducted on the composite surface runoff sample.

The lysimeter was then covered with semi-transparent tops which allowed air movement over the surface of the sediment (Figure II-9). After 6 months of drying and oxidation (Figure IV-4), the sediment was sampled and three storm events were conducted on the lysimeter. Storm events, sample collection and sample analysis were the same as the wet stage tests.

One tailed t-tests were used to compare total and filtered surface runoff concentrations to the assumed EPA Fresh and Marine Acute Water Quality Criteria for the Protection of Aquatic Life (USEPA 1987), as well as the assumed Effluent and Receiving Water Limitation standards for dredging Oakland Harbor issued by CRWQCB (Table IV-1). Contaminant concentrations less than or equal to the assumed criteria and standards were postulated as the null hypothesis. Contaminant concentrations greater than the assumed EPA Criteria served as the alternate hypothesis. A rejection of the null hypothesis indicated that values were greater than the assumed criteria or standards. All runoff concentration data was first transformed into natural logs before statistical analysis was conducted. In the absence of state water quality



Figure IV-1. Rainfall simulation on anaerobic sediment



Figure IV-2. Runoff rate measurements were taken throughout the rainfall simulation



Figure IV-3. Soil bed of anaerobic sediment just after a simulated rainfall event

standards for an undetermined disposal site, the federal water quality criteria were used to give some perspective to test results. Section 401 requires compliance with State water quality standards, rather than Federal water quality criteria.

Statistical procedures were used to compare filtered (soluble) and unfiltered (total) contaminant concentrations in surface runoff from the both wet anaerobic and dry, oxidized sediment. All runoff concentration data was first transformed into natural logs before statistical analysis was conducted. The statistical tests were conducted using SAS Analysis of Variance (ANOVA) procedure (Barr et al. 1976). The null hypothesis was that all concentrations for a particular contaminant were equal. The alternate hypothesis was that the two contaminant concentrations were not equal. Actual contaminant concentrations that were statistically different were determined using the SAS,



Figure IV-4. Soil bed of dried and oxidized sediment prior to rainfall simulation

generated 95 % confidence intervals. All statistical tests were conducted at the $P = 0.05$ level of significance. A detailed description of the tests was given by Winer 1971.

Results

Wet, unoxidized surface runoff tests

The mean suspended solids concentration was 6240 mg/l in surface runoff from the wet, unoxidized sediment (Table IV-2). Mean surface runoff pH was 7.76 and the electrical conductivity 1.39 mV/cm.

Results of the runoff tests showed that cadmium, chromium, copper, lead, and zinc in surface runoff were poorly soluble. Concentrations of filtered (soluble) metals were statistically less than unfiltered (total) concentrations (Table IV-3) except for arsenic, and silver. Runoff mercury concentrations were less than the detection limits and silver concentrations were not

Table IV-1

Water Quality Criteria and Standards (ug/l) for Comparison to Test Results

<u>Parameter</u>	<u>USEPA Marine Acute** Criteria</u>	<u>USEPA Fresh Acute** Criteria</u>	<u>Effluent* Limitation</u>	<u>Receiving* Water Limitation</u>
Arsenic	69	360	50	1
Cadmium	43	3.9	1.8	0.65
Chromium	1100	16	16	11
Copper	2.9	18	9.2	6.5
Mercury	2.1	2.4	2.4	0.012
Lead	140	82	34	--
Zinc	95	120	65	59
Tributyltin	--	--	0.080	0.020
Dibutyltin	--	--	--	--
Monobutyltin	--	--	--	--
Total Butyltin	--	--	--	--

* Limitation standards issued by California Regional Water Quality Control Board (CRWQCB) in response to a permit application by the Port of Oakland (CRWQCB 1989).

** In the absence of state water quality standards for an undetermined disposal site, the federal water quality criteria were assumed to give perspective to test results.

-- No values available.

Table IV-2

Surface Runoff Water Quality from Santa Fe Sediment

<u>Parameter</u>	<u>Wet Sediment</u>	<u>Dry Sediment</u>
Suspended Solids (mg/l)**	6240 (4780-8130)	2130 (1640-2780)
pH	7.76 (7.44-8.08)	7.73 (7.41-8.06)
Electrical Conductivity (mV/cm)	1.39 (0.71-2.08)	2.85 (2.17-3.54)

** Numbers in parenthesis represent the 95 % confidence interval about the mean.

Table IV-3
Surface Runoff Water Quality From Santa Fe Sediments Metals

<u>Parameter</u>	<u>Wet</u>		<u>Dry</u>	
	<u>Unfiltered</u>	<u>Filtered</u>	<u>Unfiltered</u>	<u>Filtered</u>
Arsenic *** (ug/L)	9.08 * (5.41-15.2)+	3.60 * (2.14-6.04)	8.27 * (4.93-13.9)	3.33 * (2.09-5.29)
Silver (ug/L)	0.078 ** (0.06-0.11)	0.068 ** (0.05-0.09)	1.15 ** (0.83-1.60)	1.05 ** (0.79-1.41)
Cadmium (ug/L)	3.41 #* (2.20-5.28)	<0.10	1.37 * (0.884-2.12)	0.085 (0.057-0.126)
Chromium (ug/L)	28.9 @#* (19.6-42.6)	1.58 (1.07-2.33)	24.0 @#* (16.3-35.4)	0.382 ** (0.270-0.540)
Copper (ug/L)	270 \$@#* (144-509)	<1.00	90.0 \$@#* (47.8-169)	2.96 ** (1.68-5.22)
Mercury (ug/L)	<0.1	<0.1	<0.1	<0.1
Lead (ug/L)	60.8 (31.2-119)	0.474 ** (0.243-0.924)	42.3 (21.7-82.5)	0.360 ** (0.201-0.664)
Zinc (ug/L)	602 \$@#* (371-977)	13.0 (8.04-21.1)	155 \$#* (95.7-252)	16.3 (10.6-25.2)

+ Numbers in parenthesis represent the 95% confidence interval about the mean.

* Mean was statistically greater than the assumed Receiving Water Limitation standard.

Mean was statistically greater than the assumed Effluent Limitation standard.

@ Mean was statistically greater than the assumed USEPA Fresh Water Acute Criteria.

\$ Mean was statistically greater than the assumed US Marine Water Criteria.

** Mean was not statistically different than RO water used for the simulated rainfall test.

statistically different than concentrations in the RO water. Concentrations of heavy metals were compared to the assumed EPA Fresh and Marine Acute Maximum Criteria for the Protection of Marine Aquatic Life, and to the assumed Effluent and Receiving Water Limitation standards issued for the Port of Oakland's permit application. Concentrations of arsenic cadmium, chromium, copper, and zinc in unfiltered samples were statistically greater than at least one of the criteria and copper and zinc were statistically greater than all of the assumed criteria or standards. Only arsenic concentrations were statistically greater than one criteria or standards for filtered runoff samples.

Concentrations of tributyltin were statistically higher in unfiltered runoff samples than in filtered samples (Table IV-4). Concentrations of all the butyltins in filtered samples were either less than the detection limits or were not statistically greater than concentrations in RO water samples. Water quality criteria were available only for Tributyltin, and only the (anaerobic unfiltered and filtered runoff) samples were statistically greater than the assumed receiving water standard.

Table IV-4
Surface Runoff Water Quality From Santa Fe Sediments Butyltins

Parameter	Wet		Dry	
	Unfiltered	Filtered	Unfiltered	Filtered
Tetrabutyltin (ng/L)	5.31 ** (3.72-7.58)	<5.00 **	1.81 ** (1.40-2.84)	1.64 ** (1.21-2.23)
Tributyltin (ng/L)	80.6 (71.7-90.6)	32.3 ** (29.2-35.8)	9.69 ** (8.76-10.7)	1.91 ** (1.73-2.12)
Dibutyltin (ng/L)	39.4 (24.4-63.7)	5.69 ** (3.75-8.63)	13.1 (8.61-19.8)	1.66 ** (1.10-2.52)
Monobutyltin (ng/L)	12.3 ** (3.02-10.5)	<6.00 ** (1.28-4.49)	15.5 ** (7.28-24.1)	8.55 ** (2.85-11.1)

+ Numbers in parenthesis represent the 95% confidence interval about the mean.

* Mean was statistically greater than the assumed Receiving Water Limitation standard.

Mean was statistically greater than the assumed Effluent Limitation standard.

** Mean was not statistically different than RO water used for the simulated rainfall test.

Only the pesticides 4,4-DDE, 4,4-DDD, 4,4-DDT, and Dieldrin were above detection limits in runoff samples from the wet, unoxidized sediment (Table IV-5). Concentrations in filtered samples were not statistically different than concentrations in unfiltered samples. USEPA water quality criteria were available for 4,4-DDE, 4,4-DDT and Dieldrin, but only 4,4-DDT exceeded the assumed EPA acute criteria for marine environments.

Many of the PAH parameters that surface runoff samples were analyzed for were greater than the detection limits (Table IV-6). In most cases concentrations were statistically greater in the filtered samples than in the unfiltered samples. Unfiltered samples with high concentrations of suspended solids have more interferences and lower recovery rates during the analytical process which causes concentrations to appear lower than in filtered samples. No parameter concentrations in either unfiltered or filtered samples exceeded any of the assumed water quality criteria or standards.

Dry, oxidized surface runoff test

Concentrations of suspended solids in runoff samples from the dry, oxidized tests were statistically less than concentrations in samples from the wet, unoxidized tests (Table IV-2). The pH of runoff samples from the dry, oxidized tests were not statistically different than samples from the wet, unoxidized tests. Electrical conductivity in samples from the dry, oxidized tests were statistically higher than in samples from the wet, unoxidized tests.

Unfiltered heavy metal concentrations in runoff from the dry, oxidized sediments were not statistically different than unfiltered concentrations from the wet, unoxidized tests (Table IV-3). Filtered concentrations were statistically less than unfiltered concentrations from the dry, oxidized sediment but were not statistically different than filtered concentrations in runoff from the wet, unoxidized sediment. Arsenic, cadmium, chromium, copper, and zinc unfiltered concentrations in runoff samples collected from the dry, oxidized sediment were statistically greater than at least one of the assumed water quality criteria or standards, but only arsenic was statistically greater than any of the assumed criteria or standards for filtered samples. Filtered concentrations of silver, chromium, copper, and lead were not statistically different than the RO water.

Unfiltered butyltin concentrations from the dry, oxidized sediment runoff samples were statistically less in samples collected from the wet, unoxidized sediment (Table IV-4). No butyltin concentrations in filtered

Table IV-5
Surface Runoff Water Quality From Santa Fe Sediments
Pesticides (ug/l)

Parameter	Wet		Dry	
	Unfiltered	Filtered	Unfiltered	Filtered
Aldrin	<0.06 **	<0.06 **	<0.06 **	<0.06 **
A-BHC	<0.06 **	<0.06 **	<0.06 **	<0.06 **
B-BHC	<0.06 **	<0.06 **	<0.06 **	<0.06 **
D-BHC	<0.06 **	<0.06 **	<0.06 **	<0.06 **
Chlordane	<0.06 **	<0.06 **	<0.06 **	<0.06 **
4,4-DDE	0.22 (0.18-0.27)	0.26 (0.22-0.32)	<0.06	<0.06
4,4-DDD	1.52 (1.11-2.07)	1.69 (1.24-2.31)	<0.06	<0.06
4,4-DDT	0.40 (0.22-0.72)	1.12 (0.62-2.00)	0.08 ** (0.05-0.15)	<0.06
Dieldrin	0.09 ** (0.06-0.13)	<0.06	<0.06	<0.06
Endosulfan I	<0.06 **	<0.06 **	<0.06 **	<0.06 **
Endosulfan II	<0.06 **	<0.06 **	<0.06 **	<0.06 **
Endosulfan Sulfate	<0.06 **	<0.06 **	<0.06 **	<0.06 **
Endrin	<0.06 **	<0.06 **	<0.06 **	<0.06 **
Endrin Aldehyde	<0.06 **	<0.06 **	<0.06 **	<0.06 **
Heptachlor	<0.06 **	<0.06 **	<0.06 **	<0.06 **
Heptachlor Epoxide	<0.06 **	<0.06 **	<0.06 **	<0.06 **
Lindane	<0.06 **	<0.06 **	<0.06 **	<0.06 **
Toxaphene	<0.6 **	<0.6 **	<0.6 **	<0.6 **
Methoxychlor	<0.12 **	<0.12 **	<0.12 **	<0.12 **
Endrin Ketone	<0.06 **	<0.06 **	<0.06 **	<0.06 **

-
- + Numbers in parenthesis represent the 95% confidence interval about the mean.
- * Mean was statistically greater than the assumed Receiving Water Limitation standard.
- # Mean was statistically greater than the assumed Effluent Limitation standard.
- @ Mean was statistically greater than the assumed USEPA Fresh Water Acute Criteria.
- \$ Mean was statistically greater than the assumed USEPA Marine Water Criteria.
- ** Mean was not statistically different than RO water used for the simulated rainfall test.

Table IV-6
Surface Runoff Water Quality From Santa Fe Sediments
PAHs (ug/L)

<u>Parameter</u>	<u>Wet</u>		<u>Dry</u>	
	<u>Unfiltered</u>	<u>Filtered</u>	<u>Unfiltered</u>	<u>Filtered</u>
Naphthalene	<49	<48	53.3 (44.7-51.4)	51.4 (42.0-62.9)
Acenaphthylene	<7.5	<7.2	<28.6	<10
Acenaphthylene	<19	<18	<28.6	<10
Fluorene	<15	<14	13.9 (10.8-18.0)	10.5 (7.84-14.1)
Phenanthrene	21.6 (16.2-28.8)	46.3 (34.7-61.8)	32.6 (24.4-43.5)	29.1 (20.9-40.7)
Anthracene	7.81 (5.47-11.1)	14.0 (9.83-20.0)	<28.6	<10
Fluoranthene	18.3 (12.5-26.9)	49.8 (33.9-73.0)	31.1 (21.2-45.6)	10.8 (6.93-16.8)
Pyrene	41.6 (27.5-63.0)	110 (72.9-167)	58.5 (38.7-88.5)	16.9 (10.5-27.3)
Benzo (A) Anthracene	12.4 (7.72-20.0)	34.0 (21.1-54.6)	15.7 (9.78-25.3)	<10
Chrysene	9.61 (5.56-16.6)	29.1 (16.8-50.4)	22.0 (12.7-38.1)	<10
Benzo (K,B) Fluoranthene	64.3 (39.1-106)	189 (115-311)	65.0 (39.6-107)	<20
Benzo (A) Pyrene	24.5 (14.5-41.6)	80.9 (47.7-137)	28.1 (16.6-47.7)	<10
Indeno (1,2,3- c,d) Pyrene	10.0 (6.32-16.0)	34.8 (21.9-55.3)	20.7 (13.0-32.8)	<10
Dibenzo (a,j) Anthracene	<6.9	6.63 (4.82-9.11)	<28.6	<10
Benzo (g,h,i) Perylene	10.5 (4.91-22.3)	42.2 (19.8-90.0)	26.2 (12.3-55.8)	<10

+ Numbers in parenthesis represent the 95% confidence interval about the mean.

* Mean was statistically greater than the assumed Receiving Water Limitation standard.

Mean was statistically greater than the assumed Effluent Limitation standard.

@ Mean was statistically greater than the assumed USEPA Fresh Water Acute Criteria.

\$ Mean was statistically greater than the assumed USEPA Marine Water Criteria.

runoff were statistically different than the RO water. No butyltin concentrations in samples from the dry, oxidized sediments were statistically different than any of the water quality criteria or standards. Pesticide concentrations in surface runoff samples from the dry, oxidized sediment were statistically less than concentrations in samples from the wet, unoxidized sediment (Table IV-5). Only 4,4-DDT concentrations in unfiltered runoff samples were above the detection limits but was less than any of the assumed criteria or standards.

Concentrations of PAHs in unfiltered surface runoff samples from the dry, oxidized sediment were generally not statistically different than concentrations in unfiltered samples from the wet, unoxidized sediment (Table IV-6). Concentrations of PAHs in filtered samples were statistically less after drying and oxidation, and were usually less than the detection limits. No surface runoff samples from the dry oxidized sediment exceeded any assumed water quality criteria or standards.

Discussion

Some changes did occur in the sediment during the drying and oxidation process, which significantly affected surface runoff water quality. The erosivity of the sediment was statistically reduced from 6240 mg/l to 2130 mg/l, however 2130 mg/l indicates the sediment was still highly erosive after drying and oxidation. Unlike most other sediment tested by the WES, surface runoff pH levels were not significantly changed after the sediment had dried and oxidized. Electrical conductivity was statistically higher after drying, and oxidation. The values were however not practically or significantly different, and the concentrations were relatively low compared to many marine sediments.

Concentrations of heavy metals in surface runoff were highest in unfiltered samples collected from the wet, unoxidized sediments, and except for arsenic were mostly insoluble and bound to the suspended solids during the wet, unoxidized stage of the sediments. Silver and mercury concentrations were close to or less than the detection limits where analytical variability was relatively high and statistical differences not detected. Tributyltin concentrations were highest in the unfiltered runoff from the wet, unoxidized sediment, and pesticides and PAHs were highest in filtered samples from the wet, unoxidized sediment.

Drying and oxidation, mostly reduced concentrations of contaminants in surface runoff. Total heavy metal concentrations were statistically reduced because of the decrease in erosivity of the sediment. Unlike many sediments tested at the WES heavy metals such as cadmium, copper, lead, and zinc did not become statistically more soluble; but remained associated mostly with the particulates in surface runoff. Total and soluble butyltins, pesticides, and PAHs were significantly less after drying, and oxidation, and soluble concentrations were mostly less than or near detection limits.

Contaminant concentrations that exceed water quality criteria or standards were mostly total concentrations or contaminants associated with particulates in surface runoff (Table IV-7). Arsenic was the only contaminant from either the wet, unoxidized sediment or the dry, oxidized sediment with a soluble concentration that exceeded any of the assumed water quality criteria or standard. Soluble arsenic exceeded the assumed Receiving Water Limitation standards by about 2 ug/l.

Table IV-7
Surface Runoff Contaminants Exceeding
Assumed Water Quality Criteria

<u>Test</u>	<u>USEPA Marine Acute Criteria</u>	<u>USEPA Fresh Acute Criteria</u>	<u>Effluent Limitation</u>	<u>Receiving Water Limitation</u>
Unfiltered, Wet, Unoxidized	Copper Zinc 4,4-DDT	Chromium Copper Zinc	Cadmium Chromium Copper Zinc	Arsenic Cadmium Chromium Copper Zinc Tributyltin
Filtered, Wet, Unoxidized	4,4-DDT	none	none	Arsenic
Unfiltered, Dry, Oxidized	Copper Zinc	Chromium Copper	Chromium Copper Zinc	Arsenic Cadmium Chromium Copper
Filtered, Dry, Oxidized	none	none	none	Arsenic

Biological Evaluation

Aquatic bioassay tests were performed on whole, unfiltered water samples obtained from the WES rainfall simulator. This system provides replicate water samples on consecutive days for chemical analyses. For these bioassays, gallon samples from three days were composited and tested as one composited runoff sample. Samples generally were clear liquid with a 0.5 cm layer of grey sediment at the bottom of the jar. This sediment was resuspended to the water column prior to the bioassay tests. Salinity of the runoff samples was very low, 0 to 1 parts per thousand (ppt). Bioassays were conducted at one salinity, 24 ppt, by using a small volume of high salinity (80 ppt) laboratory water to adjust the runoff sample.

Test species were the Pacific mysid, Neomysis mercedes and Daphnia magna. Animals were exposed to different percentages of unfiltered water samples for 96 hours in a temperature-controlled environmental chamber. Test temperatures were 18-20 degrees C and photoperiod was 14:10 hours L:D. Test chambers were one liter beakers, each containing 800 ml of test water and 10 test animals; there were five replicate beakers for each test treatment. Suspended sediment was allowed to settle during the bioassay. Controls were exposed to clean laboratory water used to hold and culture the Neomysis. This water was also used to dilute the runoff water when necessary. For example, a 50 % beaker contained 400 ml of runoff water and 400 ml of clean culture water of the proper salinity. Test animals were observed during the tests but actual counts of each beaker were only possible at the end of the 96-hour test period. Dissolved oxygen concentrations in the beakers were normally greater than 6 parts per million (ppm) and at times were measured as high as 12-14 ppm due to algae growth. The pH levels of the test waters were in the normal range for saltwater, 7.6 - 8.4. All bioassays were started within 3 days after water samples were obtained. Samples were held under refrigeration while waiting for the next days sample or while animals and test equipment were being prepared.

Results and Discussion

Table IV-8 shows percent survival of Neomysis exposed to different concentrations of runoff water from initial, wet sediment, compared to controls.

Table IV-8
Percent Survival of Neomysis Exposed to Santa Fe Channel
Runoff Water at 24 ppt Salinity for 96 hours

<u>Treatment</u>		<u>Percent survival</u>
Controls	1 -	90
	2 -	100
	3 -	100
	4 -	100
	5 -	100
10%	1 -	100
	2 -	100
	3 -	90
	4 -	90
	5 -	100
50%	1 -	90
	2 -	100
	3 -	80
	4 -	90
	5 -	100
100%	1 -	90
	2 -	100
	3 -	100
	4 -	100
	5 -	100

Data are for the Neomysis at 24 ppt salinity. Table IV-9 shows Daphnia bioassays of dry (after six months) sediment runoff water.

Exposure of these sensitive test animals to Santa Fe channel sediment runoff water showed little potential for aquatic toxicity. Mean survival was usually greater than 90 percent for all treatments, even for animals exposed to 100 percent runoff water. The Daphnia, in some cases, showed evidence that fine sediment particles were attaching to their bodies and physically affecting them. Fine sediment particles may have made it more difficult for them to swim normally. This was more likely to occur during the dry sediment (after six months) bioassays of the Daphnia. The data from these bioassays do not, in any way, indicate any potential for aquatic toxicity associated with this runoff water.

Table IV-9

Percent Survival of Daphnia Exposed to Dry (After Six Months)Santa Fe Channel Sediment Runoff water for 96 hours

<u>Treatment</u>		<u>Percent Survival</u>
Controls	1 -	100
	2 -	100
	3 -	100
	4 -	100
	5 -	100
50%	1 -	100
	2 -	90
	3 -	100
	4 -	90
100%	1 -	90
	2 -	100
	3 -	100
	4 -	100

Surface Runoff Impacts and Controls

Contaminants in surface runoff from the Santa Fe channel sediments were mostly bound to the sediment particulates. Significant quantities of arsenic, cadmium, chromium, copper, zinc, tributyltin, and 4,4-DDT could be eroded from an upland disposal site during the wet, unoxidized stage if the suspended solids were not removed from the runoff. Only arsenic exceeded any of the assumed criteria or standards for soluble contaminants. Potential surface runoff water quality problems during the wet, unoxidized period of upland disposal would therefore be mostly associated with erosion of particulates. Management of the upland disposal site to remove particulates from surface runoff, would remove 90 to 99 percent of all contaminants in surface runoff. A very small mixing zone ratio of 3 to 1 would be required to dilute soluble arsenic to the assumed Receiving Water Quality Limitation standard.

Potential problems in surface runoff from dry, oxidized sediments are similar to those in surface runoff from the wet, unoxidized sediment. Again, only soluble arsenic exceeded the assumed Receiving Water Quality Limitation standard in both sediments. Consideration of a small mixing zone and removal of the suspended solids should eliminate the need for further restrictions particularly with regard to treatment of soluble contaminants. A mixing zone of less than 10 to 1 would be required to dilute unfiltered contaminant

concentrations to less than or equal to the strictest assumed criteria or standard, and a mixing zone of about 3 to 1 would be required for soluble arsenic.

PART V: LEACHATE TEST

Methods and Materials

Oxidized sediment preparation

The sediment used in aerobic testing was first placed into 38-l glass aquariums to a depth of approximately 6 cm. The sediment was allowed to oxidize at ambient temperature. Each week the sediment was thoroughly mixed to expose fresh sediment surfaces to the air. When necessary, deoxygenated distilled-deionized (DDI) water was added to the sediment to maintain the original moisture condition. At the end of six months, the sediment was again thoroughly mixed before being used in testing.

Kinetic batch testing

Batch testing was performed to determine shaking time necessary to achieve equilibrium or steady-state conditions for metals, pesticides, PAHs, and butyltin leachate concentrations. The general experimental sequence is presented in Table V-1.

For testing metal releases from anaerobic Santa Fe Channel sediment, triplicate 250-ml polycarbonate centrifuge tubes fitted with a leakproof, airtight top were loaded with 200 g of sediment and deoxygenated distilled-deionized (DDI) water at a 4:1 water-to-sediment dry weight ratio. All operations were conducted in a glove box under a nitrogen atmosphere (Figure V-1). Nineteen centrifuge tubes were loaded to allow triplicate sampling at 6 hrs, and at 1, 2, 3, 7, and 10 days and a procedure blank. Samples were placed horizontally on a reciprocating shaker at 160 strokes per minute (spm) for the allotted time. Three tubes were removed from the shaker and centrifuged at 9,000 rpm (13,000 x g) for 30 minutes. The supernatant was filtered under a nitrogen atmosphere through 0.45-um membrane filters (Figure V-2). The filtrate was acidified to pH 1 with concentrated Ultrex nitric acid and stored in plastic bottles until analyzed.

Kinetic testing for tributyltin, pesticides, and PAHs in anaerobic Santa Fe Channel sediment was conducted in specially fabricated 450-ml stainless steel centrifuge tubes (Figure V-3). Twenty-one centrifuge tubes (sufficient for three replicates), double-rinsed with acetone, were loaded with sufficient sediment and deoxygenated DDI water to obtain a 4:1 water-to-sediment dry weight ratio. The total mass (approximately 350 g) of sediment and water was adjusted to allow the tube to be safely centrifuged at 6,200 rpm (6,500 x g).

Table V-1

Experimental Sequence for Determining Appropriate Shaking Times
for Anaerobic Kinetic Testing of Santa Fe Channel Sediment

-
- Step 1 PLACE SEDIMENT IN APPROPRIATE CENTRIFUGE TUBE (STAINLESS STEEL OR POLYCARBONATE), ADD SUFFICIENT DEOXYGENATED-DISTILLED WATER TO MAINTAIN WATER-TO-SEDIMENT RATIO OF 4:1.
-
- Step 2 PLACE CENTRIFUGE TUBES FOR METALS ON RECIPROCATING SHAKER AND SHAKE AT 160 CYCLES PER MINUTE. PLACE CENTRIFUGE TUBES FOR TRIBUTYL TIN, PESTICIDES, AND PAHs IN ROTARY MIXER AND TURN AT 40 REVOLUTIONS PER MINUTE.
-
- Step 3 REMOVE TUBES (ENOUGH FOR TRIPPLICATE SAMPLES) FROM SHAKER AT APPROPRIATE INTERVALS: 1, 2, AND 7 DAYS FOR TRIBUTYL TIN, PESTICIDES, AND PAHs AND 6 HR, 1, 2, 3, 7, AND 10 DAYS FOR METALS.
-
- Step 4 CENTRIFUGE FOR 30 MINUTES AT 6,500 X g FOR TRIBUTYL TIN, PESTICIDES, AND PAHs AND 13,000 x g FOR METALS.
-
- Step 5 FILTER CENTRIFUGED LEACHATE THROUGH A 0.45-um PORE SIZE MEMBRANE FILTER FOR METALS, AND THROUGH A WHATMAN GF/D GLASS-FIBER PREFILTER AND A GELMAN AE GLASS-FIBER FILTER WITH A 1-um NOMINAL PORE SIZE FOR TRIBUTYL TIN, PESTICIDES, AND PAHs.
-
- Step 6 ACIDIFY LEACHATE FOR METALS AND PAH ANALYSIS WITH ULTREX NITRIC ACID. STORE SAMPLES FOR ANALYSIS OF TRIBUTYL TIN, PESTICIDES, AND PAHs IN GLASS BOTTLES AND FREEZE UNTIL ANALYSIS. STORE LEACHATE FOR METALS ANALYSIS IN PLASTIC BOTTLES.
-

All operations were conducted under a nitrogen atmosphere. The tubes were placed in a rotary tumbler and turned end over end at 40 rpm for periods of 1, 2, and 7 days. At the appointed times, the samples were removed from the tumbler and centrifuged for 30 min. Resulting supernatants were filtered through a Whatman GF/D prefilter and a Gelman AE filter with a nominal pore size of 1.0 um. The filters (Whatman GF/D prefilters and Gelman AE filters)



Figure V-1. Anaerobic sediments were processed under a nitrogen atmosphere in a glove box

are binderless glass-fiber and contain no detectable organic contaminants. As a further precaution against contamination, the filters used in this study were combusted at 400 °C prior to use. Filtration was conducted under a nitrogen atmosphere; samples for tributyltin were frozen immediately in acetone-rinsed 2-l glass bottles until analyzed. Samples for pesticides and PAHs were acidified with Ultrex nitric acid and stored in acetone-rinsed 2-l glass bottles at 4 °C until analyzed.

Sequential batch testing

A 4:1 water-to-sediment ratio and a shaking time of 24 hr were used in the sequential batch leach tests for Santa Fe Channel sediment. General test procedures for assessing steady-state leachate and sediment metal, pesticide, PAH and tributyltin concentrations are detailed in Table V-2. Sequential batch tests for metals under anaerobic conditions were conducted in triplicate



Figure V-2. Filtering of anaerobic sediment leachates are performed in a nitrogen atmosphere



Figure V-3. Centrifuge tubes with anaerobic sediment are stored under a nitrogen atmosphere

Table V-2

Test Sequence for Sequential Batch Leaching of Anaerobic Santa Fe
Channel Sediment for Metals, Pesticides, PAHs, and Tributyltin

-
- Step 1 LOAD SEDIMENT INTO APPROPRIATE CENTRIFUGE TUBES; 250-ML POLYCARBONATE FOR METALS AND 450-ML STAINLESS STEEL FOR TRIBUTYLTIN, PESTICIDES, AND PAHs. ADD SUFFICIENT WATER TO EACH TUBE TO BRING FINAL WATER-TO-SEDIMENT RATIO TO 4:1. LOAD SUFFICIENT NUMBER OF STAINLESS STEEL TUBES TO OBTAIN SUFFICIENT LEACHATE FOR ANALYSIS.
-
- Step 2 GO THROUGH STEP 2 IN TABLE V-1.
-
- Step 3 CENTRIFUGE FOR 30 MIN AT 6,500 x g FOR TRIBUTYLTIN, PESTICIDES, AND PAHs AND 13,000 x g FOR METALS.
-
- Step 4 FILTER LEACHATE THROUGH 0.45-UM MEMBRANE FILTERS FOR METALS OR THROUGH WHATMAN GD/F GLASS-FIBER PREFILTERS FOLLOWED BY GELMAN AE GLASS-FIBER FILTERS OF 1.0-UM NOMINAL PORE SIZE FOR TRIBUTYLTIN, PESTICIDES, AND PAHs. SET ASIDE A SMALL AMOUNT OF LEACHATE PRIOR TO ACIDIFICATION FOR ANALYSIS OF pH, CONDUCTIVITY, AND TOC.
-
- Step 5 RETURN TO STEP 2 AFTER REPLACING LEACHATE WITH DEOXYGENATED-DISTILLED WATER. REPEAT THE ENTIRE PROCEDURE THE DESIRED NUMBER OF TIMES.
-

Notes: Testing sequence is the same for aerobic sediments except that anaerobic integrity is not maintained.

250-ml polycarbonate centrifuge bottles with leakproof caps. Each centrifuge tube was loaded under a nitrogen atmosphere with anaerobic Santa Fe Channel sediment and deoxygenated DDI water to a 4:1 water-to-sediment ratio. Tubes were mechanically shaken for 24 hr and centrifuged at 13,000 x g for 30 min. Most of the leachate from each 250-ml centrifuge bottle was filtered through a 0.45-um membrane filter. The unfiltered leachate was analyzed for pH using a combination electrode and a millivolt meter and for conductivity using a Yellow Springs Instrument Company conductivity meter and cell. Fresh

deoxygenated DDI water was added to replace the leachate removed for analysis. The procedure described above for sequentially contacting anaerobic Santa Fe Channel sediment with clean water was repeated seven times. The same general procedure was repeated for aerobic batch leach tests for metals, except that anaerobic conditions were not maintained.

Testing of Santa Fe Channel sediment for butyltin compounds, pesticides, and PAHs was conducted as described for metals except that 450-ml stainless steel centrifuge tubes were used. Filtration procedures used for butyltin compounds, pesticides, and PAHs were as previously described for kinetic batch testing of these parameters. A subsample of filtered leachate was set aside from both the anaerobic and aerobic tests for analysis of total organic carbon. After each cycle, the sediment was remixed with DDI water, shaken for 24 hr, and then processed as previously described. Three replicates were taken through six leach cycles for the anaerobic and aerobic testing.

Column leach testing

Column leach tests were conducted in large diameter-to-length columns designed specifically for sediment and dredged material leaching (Figure V-4). The apparatus was designed to simulate anaerobic leaching of dredged material in a continuous flow mode, minimize wall effects, hold pore water velocities to less than 10^{-5} cm/sec, elute 10 or more pore volumes in six months, and produce sufficient sample volume for chemical analysis of fractional pore volume samples. Design of a leaching column with these performance characteristics for sediments with low hydraulic conductivities was described by Myers, Gambrell, and Tittlebaum (1991).

Sediment was placed in leaching columns at in-situ water content in small increments, and manually vibrated with a spatula to eliminate air voids. Since the water content of the sediment was high, the sediment was easily worked using manual vibration techniques. Water content and specific gravity were determined according to methods described in Corps of Engineers (1970). These data were used to calculate sediment porosity. After the columns were filled, distilled-deionized water was pumped in upflow mode through the columns with a constant volume pump.

Separate column leach tests were run for metals and organic contaminant analysis because of the differences in sample volumes needed to conduct metal analysis (approximately 100 ml) and organic analysis (approximately 1000 ml) and different preservation techniques required. Column leach tests were conducted in triplicate for metals. Single columns were run for pesticides,

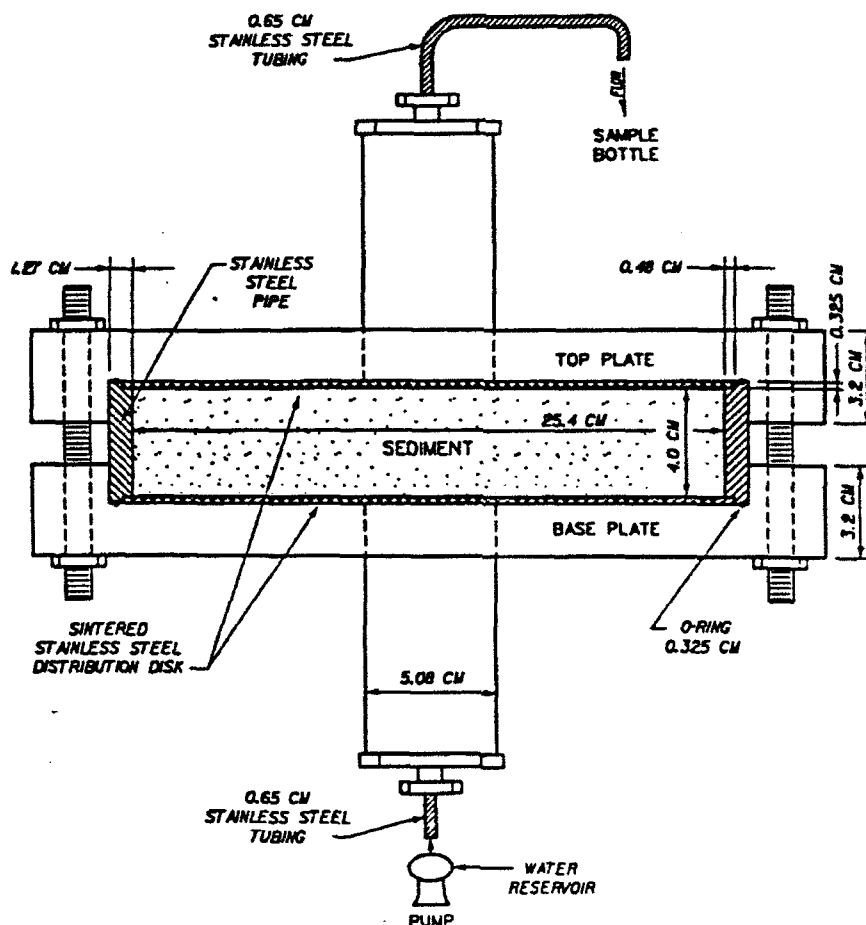


Figure V-4. Dredged material leaching column

PAHs, and tributyltin because separate, one liter samples were needed for analysis of each of these parameters. For each column leachate sample collected, the volume of leachate and time of collection were recorded. As leachate from columns conducted for metals was collected, pH was adjusted to less than 2 using Ultrex nitric acid. Samples collected for metal analysis were split for metal and total organic carbon analysis. Leachates for PAH, pesticide, and tributyltin analysis were collected in amber, acetone rinsed, glass jars. Leachates from columns conducted for organics were not pH adjusted or otherwise altered. After each leachate sample for chemical (metals or organics) analysis was collected, an additional sample of 15 to 20 ml was collected and analyzed for pH and electrical conductivity.

Chemical analysis

Leachate and sediment samples were analyzed by Battelle Northwest for tetrabutyltin (TETBT), tributyltin (TBT), dibutyltin (DBT), monobutyltin (MBT), naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene,

anthracene, fluoranthene, pyrene benzo(a)-Anthracene, chrysene, benzo(b) + benzo(k)-fluoranthene, benzo(a)-pyrene, indeno-(1,2,3-cd)-pyrene, dibenzo(a,h)-anthracene, benzo(g,h,i)-perylene, nickel (Ni), selenium (Se), silver (Ag), cadmium (Cd), lead (Pb), mercury (Hg), arsenic (As), zinc (Zn), chromium (Cr), copper (Cu), aldrin, alpha-BHC, Beta-BHC, Delta-BHC, chlordane, 4,4-DDD, 4,4-DDE, 4,4-DDT, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, endrin aldehyde, heptachlor, heptachlor epoxide, lindane, methoxy-chlor, endrin ketone, and toxaphene.

Data and statistical analysis

All statistical analyses were conducted using methods developed by the Statistical Analysis Systems Institute (Barr et al. 1976). To test for differences between means, analysis of variance procedures were used. Prior to computation and analysis of data, method blanks were subtracted from analytical values for butyltin, pesticide, and PAH compounds. When all leachate values were below detection limits, data for that compound are not presented in tabular form within the main body of the report, but are shown in Appendix D.

Results

Sediment concentration

Concentrations of metals, butyltin compounds, pesticides, and PAH compounds are presented in Part II of this report. Concentrations of PAH, pesticides, and butyltin compounds following six months of aerobic incubation are presented in Table V-3. Concentrations of butyltin, pesticide, and PAH compounds were generally lower in concentration in the aerobic sediments compared to the anaerobic sediments except for naphthalene and 4,4-DDD which were higher in the aerobic sediment. Decreased concentrations under aerobic conditions reflects losses due to volatilization and degradation during the incubation process. Increased concentrations under aerobic conditions may be a result of slight differences in concentration between the sediment subsamples chemically analyzed and the subsamples used and oxidized for leachate testing.

Kinetic batch testing

Kinetic batch testing was performed to confirm previous experiments indicating that a 24 hour shaking time was sufficient to achieve steady-state conditions. To test this hypothesis, 1 day concentrations were compared to concentrations obtained at other sampling times during kinetic batch testing. Results showed no significant differences ($P < 0.05$) for metals and butyltin

Table V-3
Concentrations of PAH (ug/Kg)*, Pesticides (ug/Kg)**, and
Butyltins (ug/Kg)*** Compounds in Aerobic Santa Fe
Channel Sediment Following Six Months
of Incubation

<u>Parameter</u>	<u>Concentration</u>
Naphthalene*	6500
Phenanthrene	30100
Anthracene	15000
Fluoranthrene	65800
Benzo[a]anthracene	33500
Chrysene	72100
Benzo[b,j,k]fluoranthrene	234800
Benzo[a]pyrene	93300
Indeno[1,2,3-c,d]pyrene	26600
Dibenzo[a,h]anthracene	<4.000
Pyrene	123500
Fluorene	<4.000
Benzo[g,h,i]perylene	22000
Acenaphthylene	<4.000
Acenaphthene	<4.000
4,4-DDD**	0.860
4,4-DDT	95.000
4,4-DDE	14.800
Dieldrin	<3.400
Endrin Aldehyde	<1.700
Monobutyltin***	<5.100
Dibutyltin	4400
Tributyltin	2700
Tetrabutyltin	<2.400

compounds in anaerobic Santa Fe Channel Harbor sediments (Table V-4) in levels of leachate Zn, Cu, Ni, Ag, Cd, Se, dibutyltin, and monobutyltin. Therefore, one day of shaking for these compounds will reflect the highest leachate concentrations observable. Mercury concentrations were highest at the 6 hr sampling, but concentrations at the 1 day sampling did not statistically differ from concentrations at later sampling times. Arsenic leachate concentrations following 1 day of shaking were statistically equivalent to all but the 3, 7, and 10 day concentrations. Lead concentrations at 1 day were only exceeded by concentrations following 2 days.

In past leaching studies with sediments from Indiana Harbor, Indiana (Environmental Laboratory 1987a and 1987b) and Everett Harbor, Washington (Palermo et al. 1989), 1 day was sufficient for steady-state or worst-case

Table V-4

Heavy Metal* and Butyltin** Concentrations in Leachate from Anaerobic
Santa Fe Channel Sediment in Different Sampling Times

Parameter	6 Hr	Sampling Times				
		Day 1	Day 2	Day 3	Day 7	Day 10
As	13.9(1.49)	25.8(1.33)	31.5(3.87)	53.0(9.95)	107(23.8)	78.4(6.15)
Zn	101(68.5)	70.5(39.0)	53.5(7.62)	35.3(12.5)	97.7(81.8)	39.6(10.1)
Cu	17.9(3.19)	15(0.61)	22.3(2.78)	18.7(2.56)	17.0(2.09)	19.5(4.41)
Ni	21.6(1.12)	22.0(1.34)	24.1(2.72)	20.5(3.06)	38.7(15.4)	21.5(2.56)
Cr	9.74(0.32)	9.0(1.06)	11.9(1.25)	10.4(2.25)	9.56(0.52)	10.3(1.24)
Ag	0.08(0.01)	0.10(0.02)	0.14(0.02)	0.09(0.02)	0.08(0.02)	0.11(0.03)
Pb	0.86(0.42)	1.22(0.21)	3.35(0.41)	2.03(1.02)	10.7(9.98)	1.45(0.69)
Cd	0.27(0.07)	0.69(0.10)	0.52(0.14)	0.33(0.12)	0.72(0.45)	0.20(0.03)
Hg	0.14(0.10)	0.04(0)	0.11(0.03)	0.01(0)	0.01(0)	0.05(0.02)
Se	35.7(1.53)	30.1(1.69)	31.8(1.45)	32.4(2.54)	30.4(0.61)	33.7(2.12)
Monobutyltin	NT***	10.9(6.84)	6.17(3.74)	NT***	19.0(4.08)	NT***
Dibutyltin	NT***	59.4(47.9)	1.43(1.44)	NT***	7.63(2.34)	NT***

* Expressed in micrograms per liter (standard error in parenthesis).

** Expressed in nanograms per liter (standard error in parenthesis).

*** NT-Not Tested

metal concentrations to be achieved. Metals in Santa Fe Channel Harbor sediment deviated slightly from this kinetic behavior because of time of sediment-water contact, sediment salinity, and sediment oxidation status (Brannon, Myers, and Price 1990).

Kinetic testing results for PAH compounds in anaerobic Santa Fe Channel Harbor sediments (Table V-5) showed that PAH concentrations following 1 day of shaking were generally no different from leachate concentrations at later sampling periods. At the low concentration levels encountered for PAHs, detection limits and analytical method blank contamination present problems for data interpretation. Detection limits varied from sample to sample, but were generally between 4.8 and 19.2 ng/l. Analytical method blank contamination was subtracted from the analytical value reported because in many cases it constituted a large portion of the analytical value. Where the analytical method blank equaled or exceeded the leachate value, a single less than value of the analytical method blank is presented. Average values below detection limits are often noted in Table V-5 and reflect trace amounts in one or more replicate samples at a specific sampling time averaged with values that were below detection limits.

Kinetic test results for pesticide compounds showed that all were below detection limits. Detection limits were < 0.06 to 6 ug/l.

Table V-5
PAH Concentrations* in Leachate from Anaerobic Santa Fe Channel
Sediment at Different Sampling Times

Parameter	Sampling Times		
	1	2	7
Benzo(b,j,k)-fluoranthene	12.0(6.13)	8.90(4.54)	29.6(2.80)
Benzo(a)-pyrene	<4.8-16.0	<4.8-19.2	10.1(2.01)
Indeno-(1,2,3-c,d)pyrene	10.4(10.4)	<7.6-30.4	<7.6
Naphthalene	301(12.7)	106(23.9)	161(119)
Phenanthrene	32.2(32.2)	<12.8-50.2	25.4(8.22)
Fluoranthrene	24.6(20.6)	<8.0-32.0	26.2(7.36)
Pyrene	50.3(8.58)	37.4(2.08)	60.5(8.55)
Benzo(a)-Anthracene	7.4(7.41)	<5.6-22.4	2.30(2.30)
Chrysene	<4.8-16.0	<4.8-19.2	4.13(2.07)
Fluorene	<9.6-32.0	<9.6-38.4	3.57(3.57)
Anthracene	<5.6-18.7	<5.6-22.4	7.00(0.42)
Acenaphthene	<12.0-40.0	<9.6-38.4	6.37(6.37)

* Expressed in nanograms per liter (standard error in parenthesis).

Sequential Batch Leaching

General leachate quality

Leachate pH and conductivity values for anaerobic and aerobic sequential batch leaching tests for Santa Fe Channel sediment are presented in Table V-6. The pH during anaerobic leaching was approximately 1 unit higher than during aerobic leaching from Santa Fe Channel sediment during the first leach cycle, but values were similar during the remainder of the leach cycles.

Table V-6

Leachate pH and Conductivity (millisiemens) in Santa Fe Channel Sequential Batch Leachate Testing

Cycle	Anaerobic		Aerobic	
	pH	Conductivity	pH	Conductivity
1	8.35(0.003)	7.55(0.05)	7.33(0.10)	1.86(0.04)
2	8.45(0.04)	1.73(0.05)	8.3(0.05)	0.62(0.01)
3	8.45(0.07)	0.83(0.01)	8.5(0.05)	0.35(0.009)
4	7.72(0.10)	0.75(0.04)	8.23(0.03)	0.23(0.003)
5	7.83(0.04)	0.46(0.009)	8.23(0.03)	0.18(0.003)
6	7.77(0.06)	0.35(0.003)	8.17(0.03)	0.17(0.003)

* Standard error in parenthesis.

Initial conductivities of anaerobic sediment was higher than that of oxidized Santa Fe Channel sediment (Table V-6). Conductivity decreased as leaching proceeded, reaching relatively constant values by the fifth leach cycle. This reflected a washout of salts during the course of leaching.

Anaerobic metal and butyltin releases

Steady-state metal and butyltin concentrations in leachate (C) and sediment (q) obtained from the sequential batch leaching tests for anaerobic Santa Fe Channel sediment are presented in Tables V-7 and V-8, respectively. Zn, Cu, Ni, Cr, Pb, and Cd exhibited peak leachate concentrations in the fourth leach cycle, then decreased. Mercury exhibited a peak in the fifth and sixth leach cycle. Arsenic concentrations peaked during the fifth leach cycle while Hg peaked over the fifth and sixth leach cycles. Selenium peaked at the first leach cycle. Butyltin concentrations generally peaked between the first and fourth leach cycles. Trace amounts of tetrabutyltin were found in one leachate sample even though this compound was not present in the sediment.

Table V-7

Heavy Metal* and Butyltin** Concentrations in Leachate from Anaerobic
Santa Fe Channel Sediment in Different Leach Cycles

Parameter	Leach Cycle						
	1	2	3	4	5	6	7
As	26.6(3.33)	24.3(2.09)	50.5(6.98)	54.4(6.46)	64.4(10.1)	42.3(11.3)	12.6(1.68)
Zn	73.7(41.9)	48.5(17.5)	240(19.1)	527(73.5)	122(19.5)	114(9.62)	58.2(16.9)
Cu	9.79(1.09)	40.9(4.08)	379(3.06)	584(24.9)	161(17.9)	69.0(21.5)	33.3(9.20)
Ni	18.1(2.83)	10.8(0.15)	69.7(0.88)	151(8.20)	41.7(3.70)	15.5(5.41)	7.63(2.98)
Cr	6.32(0.28)	6.22(0.61)	69.5(1.53)	192(19.4)	39.9(2.16)	16.3(2.22)	7.50(2.71)
Ag	0.10(0.02)	0.11(0.02)	0.06(0.01)	0.11(0)	0.14(0.02)	0.10(0.02)	0.03(0.01)
Pb	0.76(0.14)	19.3(1.53)	154(13.5)	193(29.0)	50.7(4.31)	20.5(7.77)	9.21(3.30)
Cd	0.91(0.17)	1.32(0.09)	2.99(0.49)	5.52(0.33)	3.07(1.00)	1.40(0.46)	0.80(0.28)
Hg	0.05(0.03)	0.02(0)	0.02(0.01)	0.10(0.03)	0.16(.08)	0.19(0.16)	0.01(0.01)
Se	27.1(0.65)	4.35(0.93)	2.7(0.20)	4.15(0.63)	2.83(0.55)	2.92(0.42)	4.18(0.21)
Monobutyltin	12.6(5.04)	17.9(6.12)	5.80(1.26)	6.63(2.87)	8.87(1.00)	7.37(1.07)	NT***
Dibutyltin	28.0(13.3)	48.8(3.06)	26.0(5.53)	18.4(8.71)	10.2(3.70)	4.47(1.01)	NT***
Tributyltin	5.93(3.18)	57.6(26.9)	67.4(11.8)	40.8(15.5)	18.0(7.55)	8.00(3.56)	NT***
Tetrabutyltin	0.57(0.57)	<1.1-1.5	<1.5-2.0	<1.4-2.0	<1.6-2.1	<1.4-2.0	NT***

* Expressed in micrograms per liter (standard error in parenthesis).

** Expressed in nanograms per liter (standard error in parenthesis).

*** NT-Not Tested

Table V-8

Heavy Metal* and Butyltin** Sediment Concentrations in Anaerobic
Santa Fe Channel in Different Leach Cycles

Parameter	Leach Cycle						
	1	2	3	4	5	6	7
As	8.34(0.01)	8.25(0.02)	8.05(0.02)	7.83(0.05)	7.57(0.07)	7.40(0.10)	7.35(0.10)
Zn	116.7(0.17)	116.5(0.24)	115.6(0.16)	113.5(0.19)	113(0.13)	113(0.13)	112269(0.18)
Cu	56.4(0)	56.2(0.02)	54.7(0.02)	52.3(0.10)	51.7(0.15)	51.4(0.22)	51.3(0.25)
Ni	80.7(0.01)	80.6(0.01)	80.4(0.02)	79.8(0.03)	79.6(0.02)	79.5(0.01)	79.5(0.02)
Cr	186.2(0)	186.2(0)	185.9(0.01)	185.2(0.07)	185.0(0.07)	9(0.06)	184.9(0.05)
Ag	0.26(0)	0.26(0)	0.26(0)	0.26(0)	0.26(0)	0.26(0)	0.26(0)
Pb	29.1(0)	29.0(0)	28.4(0.05)	27.6(0.16)	27.4(0.18)	27.4(0.20)	27.3(0.22)
Cd	0.69(0)	0.69(0)	0.68(0)	0.66(0)	0.64(0)	0.64(0)	0.63(0)
Hg	0.293(0)	0.293(0)	0.293(0)	0.293(0)	0.292(0)	0.292(0)	0.292(0)
Se	0.066(0)	0.049(0)	0.038(0)	0.021(0)	0.010(0)	0	0
Monobutyltin	1.95(0.02)	1.88(0.03)	1.85(0.04)	1.83(0.03)	1.79(0.03)	1.76(0.03)	NT***
Dibutyltin	5.86(0.05)	5.67(0.06)	5.56(0.84)	5.49(0.05)	5.45(0.06)	5.43(0.06)	NT***
Tributyltin	6.33(0.01)	6.10(0.12)	5.83(0.16)	5.66(0.23)	5.59(0.22)	5.56(0.23)	NT***
Tetrabutyltin							
							-- Not Detected in Sediment (<0.6-0.8) --

* Expressed in milligrams per kilogram (standard error in parenthesis).

** Expressed in micrograms per kilogram (standard error in parenthesis).

*** NT - Not Tested

This was a possible consequence of slight differences in concentration between the sediment subsamples analyzed and used for leaching or reagent contamination during analysis.

Aerobic metal and butyltin releases

Steady-state metal and butyltin concentrations in leachate (C) and sediment (q) obtained from the sequential batch leaching tests for aerobic Santa Fe Channel sediment are presented in Tables V-9 and V-10, respectively. Cu, Ni, Cr, Ag, Pb, and Cd exhibited peak leachate concentrations in the fifth leach cycle, then decreased. Arsenic exhibited a peak in the third and sixth leach cycles, while Zn peaked in the third and fifth leach cycles. Selenium concentrations peaked during the first leach cycle. Butyltin concentrations generally peaked between the fifth and sixth leach cycles. Concentrations of monobutyltin were detected in the leachate even though this compound was not detected in the sediment. This was a possible consequence of slight differences in concentration between the sediment subsamples analyzed and used for leaching or reagent contamination during analysis. Metal and tributyltin concentrations during sequential batch leaching of anaerobic and aerobic Santa Fe Channel sediment are presented in Figure V-5 for Zn and Cu and in Figure V-6 for dibutyltin and tributyltin. Leachate concentrations for these metal and butyltin compounds were higher under anaerobic conditions than under aerobic conditions.

Anaerobic PAH releases

Steady-state PAH concentrations in leachate and sediment obtained from the sequential batch leaching tests for anaerobic Santa Fe Channel sediment are presented in Tables V-11 and V-12, respectively. PAH compounds generally peaked in either the second or third leach cycle, with the exception of naphthalene, which peaked during the first leach cycle. Naphthalene was detected in the leachate even though it was not found in the sediment. This may be a result of slight differences in concentration between the sediment subsamples chemically analyzed and the subsamples tested for leaching or low level reagent contamination during analysis. Analytical method blank contamination was at times higher than the concentrations of PAHs measured in the leachate. Such instances can be identified by the presence of a single less than value in Table V-11.

Aerobic PAH releases

Steady-state PAH concentrations in leachate and sediment obtained from the sequential batch leaching tests for aerobic Santa Fe Channel sediment are

Table V-9

Heavy Metal* and Butyltin** Concentrations in Leachate from Aerobic
Santa Fe Channel Sediment in Different Leach Cycles

Parameter	Leach Cycle						
	1	2	3	4	5	6	7
AS	22.5(0.34)	38.8(1.48)	42.5(0.88)	39.6(0.82)	29.5(1.86)	42.3(2.25)	27.0(0.51)
Zn	41.0(11.2)	73.7(6.81)	237(52.6)	217(9.34)	254(10.9)	57.7(2.17)	95.5(3.74)
Cu	27.8(1.04)	92.5(2.97)	165.0(5.14)	166.3(0.88)	181.3(2.91)	53.4(2.20)	69.5(2.84)
Ni	9.88(0.63)	14.7(0.84)	46.5(1.74)	50.9(1.38)	64.1(1.04)	20.2(2.55)	29.9(2.70)
Cr	2.10(0.22)	10.4(0.31)	51.2(1.18)	52.3(2.98)	66.1(3.21)	17.4(0.64)	22.9(1.59)
Ag	0.21(0.12)	0.26(0.03)	0.42(0.04)	0.34(0.04)	0.46(0.03)	0.26(0.05)	0.32(0.02)
Pb	2.59(0.09)	13.2(0.27)	50.0(2.5)	59.7(1.12)	79.9(1.47)	15.6(0.25)	25.3(1.94)
Cd	0.54(0.11)	0.39(0.02)	0.94(0.11)	1.20(0.17)	1.39(0.10)	0.42(0.06)	0.57(0.03)
Hg	0.082(0.02)	0.017(0)	0.020(0)	0.079(0.06)	0.088(0.06)	0.010(0)	0.010(0)
Se	16.2(1.84)	7.24(1.45)	8.04(0.41)	8.52(0.24)	9.82(2.52)	10.6(1.37)	9.65(1.33)
Monobutyltin	5.67(0.98)	17.5(2.67)	15.1(1.79)	12.0(2.97)	15.5(2.52)	18.5(4.50)	NT***
Dibutyltin	10.5(1.47)	21.7(12.7)	25.9(4.52)	26.8(4.49)	27.9(6.94)	21.7(2.62)	NT***
Tributyltin	6.30(1.05)	19.3(10.9)	19.8(3.60)	13.7(5.69)	24.2(6.93)	6.07(0.57)	NT***

* Expressed in micrograms per liter (standard error in parenthesis).

** Expressed in nanograms per liter (standard error in parenthesis).

*** NT-Not Tested

Table V-10

Heavy Metal* and Butyltin** Sediment Concentrations in Aerobic
Santa Fe Channel in Different Leach Cycles

Parameter	Leach Cycle						
	1	2	3	4	5	6	7
As	8.36(0)	8.20(0)	8.03(0.01)	7.88(0.01)	7.76(0.01)	7.59(0.02)	7.48(0.02)
Zn	116.8(0.04)	116.5(0.04)	115.6(0.23)	114.7(0.23)	113.7(0.18)	113.5(0.19)	113.1(0)
Cu	56.3(0)	55.9(0.01)	55.2(0.03)	54.6(0.03)	53.8(0.02)	53.6(0.02)	53.4(0.01)
Ni	80.7(0)	80.7(0.01)	80.5(0)	80.3(0.01)	80.0(0.01)	79.9(0.02)	79.8(0.02)
Cr	186.2(0)	186.2(0)	186.0(0.01)	185.8(0.02)	185.5(0.02)	185.5(0.02)	185.4(0.02)
Ag	0.257(0)	0.256(0)	0.255(0)	0.253(0)	0.252(0)	0.251(0)	0.249(0)
Pb	29.1(0)	29.0(0)	28.8(0.01)	28.6(0.02)	28.3(0.02)	28.2(0.02)	28.1(0.02)
Cd	0.695(0)	0.694(0)	0.690(0)	0.685(0)	0.680(0)	0.678(0)	0.676(1.05)
Hg	0.293(0)	0.293(0)	0.293(0)	0.293(0)	0.292(0)	0.292(0)	0.292(0)
Se	0.110(0.01)	0.081(0.01)	0.049(0.01)	0.01(0.01)	0	0	0
Monobutyltin			-- Not Detected in Sediment(<5.1) --				
Dibutyltin	4.36(0.01)	4.27(0.05)	4.17(0.06)	4.06(0.08)	3.95(0.06)	3.86(0.07)	NT***
Tributyltin	2.68(0)	2.60(0.04)	2.52(0.05)	2.46(0.07)	2.37(0.06)	2.34(0.06)	NT***

* Expressed in milligrams per kilogram (standard error in parenthesis).

** Expressed in micrograms per kilogram (standard error in parenthesis).

*** NT-Not Tested

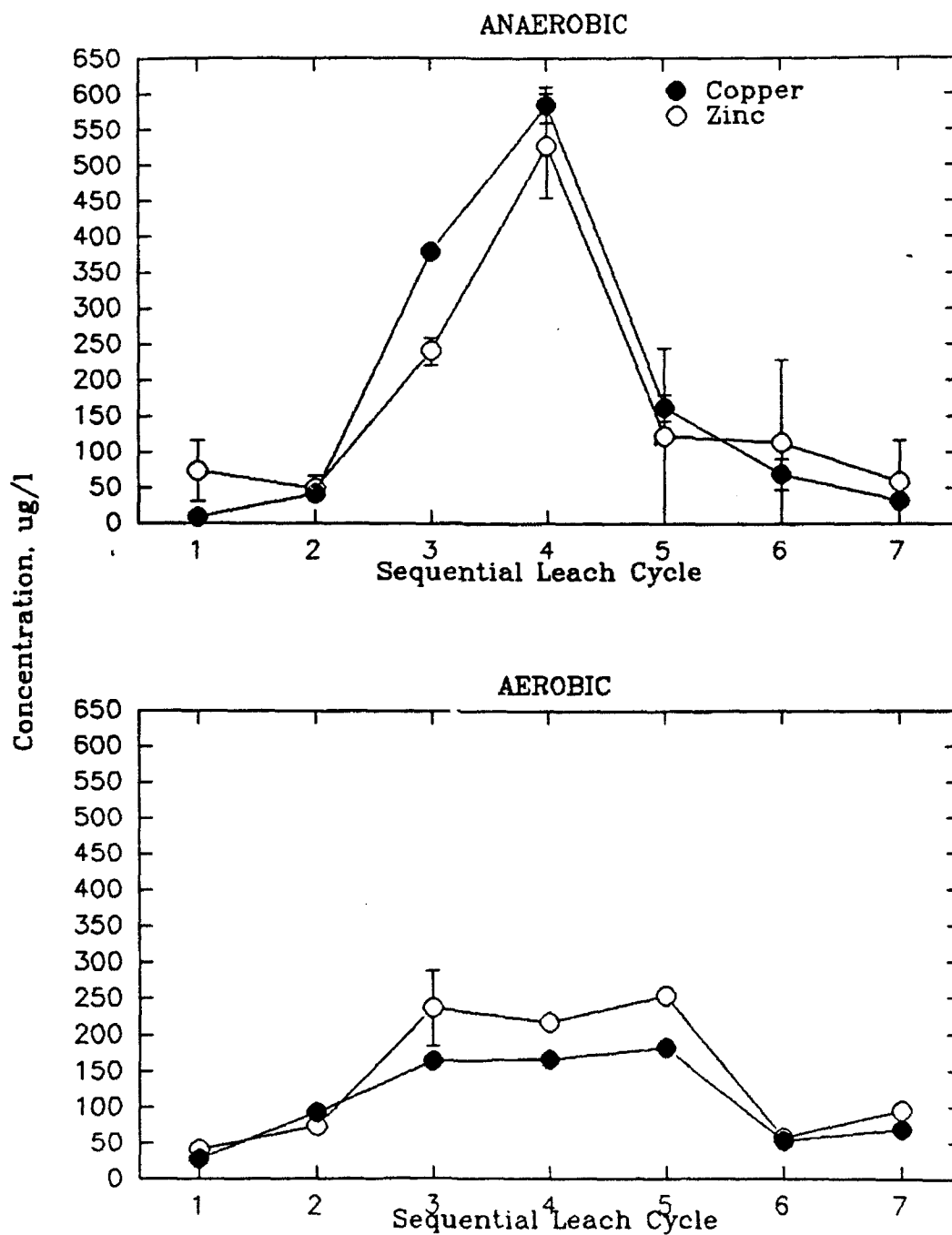


Figure V-5. Zinc and copper concentrations in sequential batch leachate from anaerobic and aerobic santa fe channel sediment

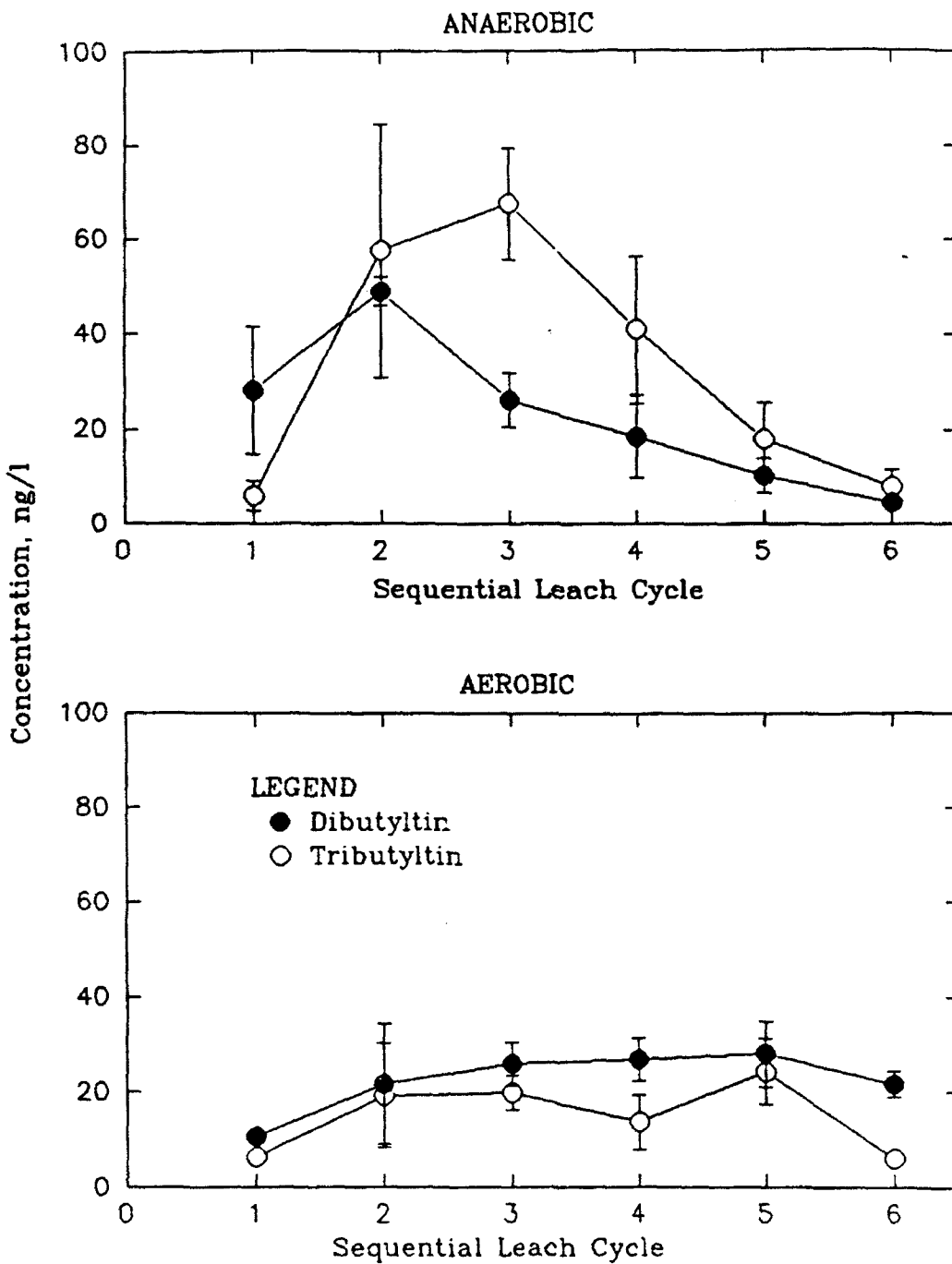


Figure V-6. Tributyltin and dibutyltin concentrations in sequential batch leachate from anaerobic and aerobic santa fe channel sediment

Table V-11
PAH Concentrations* in Leachate from Anaerobic Santa Fe Channel
Sediment in Different Leach Cycles

Parameter	Leach Cycles					
	1	2	3	4	5	6
Benzo(b,j,k)-fluoranthene	15.4(0.61)	80.5(27.2)	81.1(12.4)	18.5(3.91)	45.5(9.25)	39.1(9.89)
Benzo(a)-pyrene	5.73(0.20)	35.7(13.0)	31.3(5.42)	5.87(3.16)	17.9(4.31)	16.0(4.32)
Indeno(1,2,3-c,d)-pyrene	<7.6	26.1(10.5)	2.93(2.94)	<7.6	<7.4-7.8	<7.6
Benzo(g,h,i)-perylene	<3.8	48.0(19.4)	7.83(1.55)	<3.8	2.17(2.17)	1.77(1.77)
Naphthalene	42.6(4.48)	29.0(14.7)	<3.8	12.5(12.5)	<30.6-32.5	<31.6
Phenanthrene	22.7(0.23)	24.9(2.93)	13.3(6.72)	4.30(4.31)	4.13(4.14)	16.5(2.49)
Fluoranthrene	13.4(1.14)	20.3(3.36)	39.5(2.15)	11.5(5.75)	27.2(9.96)	26.5(8.11)
Pyrene	50.3(3.65)	77.7(12.8)	151(29.0)	43.1(9.45)	72.6(16.6)	80.2(18.8)
Benzo(a)-Anthracene	2.13(2.14)	11.1(2.57)	16.8(3.36)	2.20(2.20)	6.03(3.36)	9.67(2.40)
Chrysene	4.8	10.1(2.45)	12.6(2.78)	1.97(1.97)	6.30(0.99)	6.73(0.59)
Anthracene	4.27(2.16)	11.7(1.02)	18.1(2.31)	4.50(2.35)	7.20(1.10)	8.0(4.17)

* Expressed in nanograms per liter (standard error in parenthesis).

Table V-12

PAH Sediment Concentrations* in Anaerobic Santa Fe
Channel in Different Leach Cycles

Parameter	Leach Cycles					
	1	2	3	4	5	6
Benzo(b,j,k)-fluoranthene	625.5(0.002)	625.2(0.11)	624.9(0.07)	624.8(0.05)	624.6(0.08)	624.5(0.12)
Benzo(a)-pyrene	311.1(0)	311.0(0.05)	310.8(0.03)	310.8(0.02)	310.7(0.03)	310.7(0.05)
Indeno-(1,2,3-c,d)pyrene	183.0(0)	182.9(0.04)	182.9(0.03)	182.9(0.03)	182.9(0.03)	182.9(0.03)
Benzo(g,h,i)-perylene	229.6(0)	229.4(0.07)	229.4(0.07)	229.4(0.07)	229.4(0.08)	229.4(0.08)
Naphthalene	-- Not Detected in Sediment (<20.1-24.3) --					
Phenanthrene	62.1(0.01)	62.0(0.01)	61.9(0.03)	61.9(0.04)	61.9(0.02)	61.8(0.02)
Fluoranthrene	105.1(0)	105.0(0.01)	104.8(0.01)	104.8(0.02)	104.7(0.06)	104.6(0.09)
Pyrene	196.6(0.01)	196.3(0.05)	195.7(0.08)	195.5(0.12)	195.2(0.15)	194.9(0.18)
Benzo(a)-Anthracene	144.8(0)	144.8(0)	144.7(0.01)	144.7(0.02)	144.7(0.01)	144.7(0.01)
Chrysene	158.8(0)	158.8(0.01)	158.7(0)	158.7(0.01)	158.7(0.01)	158.7(0.01)
Anthracene	38.5(0.01)	38.5(0.01)	38.4(0.01)	38.4(0.02)	38.3(0.02)	38.3(0.01)
Acenaphthene	-- Not Detected in Sediment (<11.6-12.4) --					

* Expressed in micrograms per kilogram (standard error in parenthesis).

presented in Tables V-13 and V-14, respectively. Leachate concentrations of benzo(g,h,i)-perylene, naphthalene, and phenanthrene peaked in the second leach cycle. Unlike the situation for anaerobic sediments, low concentrations of naphthalene were found in aerobic Santa Fe Channel sediment. However, acenaphthylene, fluorene, and acenaphthene were detected at times in the leachate but were not detected in the aerobic Santa Fe Channel sediment. Possible reasons for this occurrence are presented previously in reference to similar occurrences in anaerobic PAH releases.

Leachate concentrations of benzo (b,k)-fluoranthene, benzo (a)-pyrene, and indeno(1,2,3-c,d)-pyrene peaked during the third leach cycle. Fluoranthene, pyrene, benzo(a)-anthracene, chrysene, acenaphthylene, and anthracene peaked during the fourth leach cycle.

Fluoranthrene and pyrene concentrations during sequential batch leaching of anaerobic and aerobic Santa Fe Channel sediment is presented in Figure V-7. Leaching patterns for PAHs from Santa Fe Channel sediment were similar to those observed for PCBs during sequential leaching from other saline sediments (Brannon et al. 1991). Leachate concentrations, however, of fluoranthrene and pyrene were higher in the aerobic leachate than in anaerobic leachate even though sediment concentrations generally decreased following sediment oxidation. This pattern of higher concentrations of fluoranthrene and pyrene during leaching of aerobic compared to anaerobic sediments was repeated for most PAH compounds tested.

Anaerobic pesticide releases

Steady-state pesticide concentrations in leachate and sediment obtained from the sequential batch leaching tests for anaerobic Santa Fe Channel sediment are presented in Tables V-15 and V-16, respectively. Pesticide compounds generally peaked in the third leach cycle, with the exception of endrin aldehyde which was detected only during the first leach cycle. 4,4-DDD also exhibited a secondary peak during the sixth leach cycle. Trace concentrations of 4,4-DDE and endrin aldehyde were detected in the leachate even though these constituents were not present in the sediment. This may be a result of slight differences in concentration between the sediment subsamples chemically analyzed and the subsamples tested for leaching or reagent contamination during analysis.

Aerobic pesticide releases

Steady-state pesticide concentrations in leachate and sediment obtained from the sequential batch leaching tests for aerobic Santa Fe Channel sediment

Table V-13

PAH Concentrations* in Leachate from Aerobic Santa Fe Channel
Sediment in Different Leach Cycles

Parameter	Leach Cycles					
	1	2	3	4	5	6
Benzo(b,k)-fluoranthene	119.8(3.02)	423.6(78.5)	648.7(64.0)	291.7(75.2)	164.1(41.3)	123.9(20.2)
Benzo(a)-pyrene	46.8(1.72)	166.1(25.0)	219.5(19.7)	101.3(28.8)	52.1(13.2)	44.1(8.48)
Indeno(1,2,3-c,d)-pyrene	<22.0-66.7	40.4(6.42)	41.1(3.48)	18.8(18.8)	<19.1-22.5	<19.620.1
Benzo(g,h,i)-perylene	<22.0-66.7	51.9(5.68)	40.8(3.35)	15.1(15.1)	7.47(7.48)	<19.6-20.1
Naphthalene	15.9(7.96)	25.1(4.64)	13.9(1.59)	5.07(1.34)	1.90(1.71)	4.03(4.04)
Phenanthrene	21.8(13.4)	36.5(5.70)	19.3(2.71)	9.50(1.84)	8.40(8.41)	<10.1
Fluoranthrene	40.4(3.47)	75.6(9.80)	144.9(20.9)	318.5(5.30)	90.2(8.21)	63.5(13.4)
Pyrene	94.4(10.6)	199.5(34.9)	372.7(33.8)	744.5(130)	194.5(10.7)	137.6(26.5)
Benzo(a)-Anthracene	9.30(4.66)	33.5(5.66)	60.1(6.36)	92.4(23.5)	30.7(1.92)	21.0(4.54)
Chrysene	14.7(7.28)	34.3(5.25)	58.2(3.84)	94.2(15.7)	33.3(1.92)	28.2(5.63)
Acenaphthylene	<11.0-33.3	3.53(3.54)	3.70(3.70)	10.8(5.42)	<9.6-10.7	<9.8-10.1
Fluorene	<11.0-33.3	<9.6-12.2	<9.1-10.4	5.63(5.64)	8.03(4.02)	<9.8-10.1
Anthracene	6.10(6.11)	22.2(2.52)	29.5(1.94)	32.7(5.29)	<9.6-10.7	<9.8-10.1
Acenaphthene	10.2(5.56)	3.63(3.64)	<9.1-10.4	4.0(4.0)	<9.6-10.7	<9.8-10.1

* Expressed in nanograms per liter (standard error in parenthesis).

Table V-14

PAH Sediment Concentrations* in Aerobic Santa Fe Channel
in Different Leach Cycles

Parameter	Leach Cycles					
	1	2	3	4	5	6
Benzo(b,k)-fluoranthene	240.9(0.01)	239.2(0.01)	236.6(0.30)	235.5(0.32)	234.8(0.42)	234.3(0.36)
Benzo(a)-pyrene	93.1(0.01)	92.5(0.11)	91.6(0.10)	91.2(0.12)	91.0(0.14)	90.8(0.12)
Indeno-(1,2,3-c,d)pyrene	26.6(0)	26.4(0.03)	26.3(0.03)	26.2(0.06)	26.2(0.06)	26.2(0.06)
Benzo(g,h,i)-perylene	22.0(0)	21.8(0.02)	21.6(0.03)	21.6(0.06)	21.5(0.07)	21.5(0.07)
Naphthalene	6.4(0.03)	6.3(0.04)	6.3(0.05)	6.3(0.04)	6.3(0.04)	6.2(0.05)
Phenanthrene	30.0(0.05)	29.9(0.07)	29.8(0.08)	29.8(0.08)	29.7(0.05)	29.7(0.05)
Fluoranthrene	65.6(0.01)	65.3(0.04)	64.8(0.07)	63.5(0.19)	63.1(0.22)	62.9(0.19)
Pyrene	123.1(0.04)	122.3(0.16)	120.8(0.11)	117.9(0.41)	117.1(0.45)	116.5(0.34)
Benzo(a)-Anthracene	33.5(0.02)	33.3(0.03)	33.1(0.02)	32.7(0.10)	32.6(0.10)	32.5(0.10)
Chrysene	72.0(0.03)	71.9(0.03)	71.7(0.02)	71.3(0.06)	71.2(0.05)	71.1(0.07)
Acenaphthylene		-- Not Detected in sediment (<4.0)	--			
Fluorene		-- Not Detected in Sediment (<4.0)	--			
Anthracene	15.0(0.02)	14.9(0.03)	14.8(0.03)	14.6(0.01)	14.6(0.01)	14.6(0.01)
Acenaphthene		-- Not Detected in Sediment (<4.0)	--			

* Expressed in micrograms per kilogram (standard error in parenthesis).

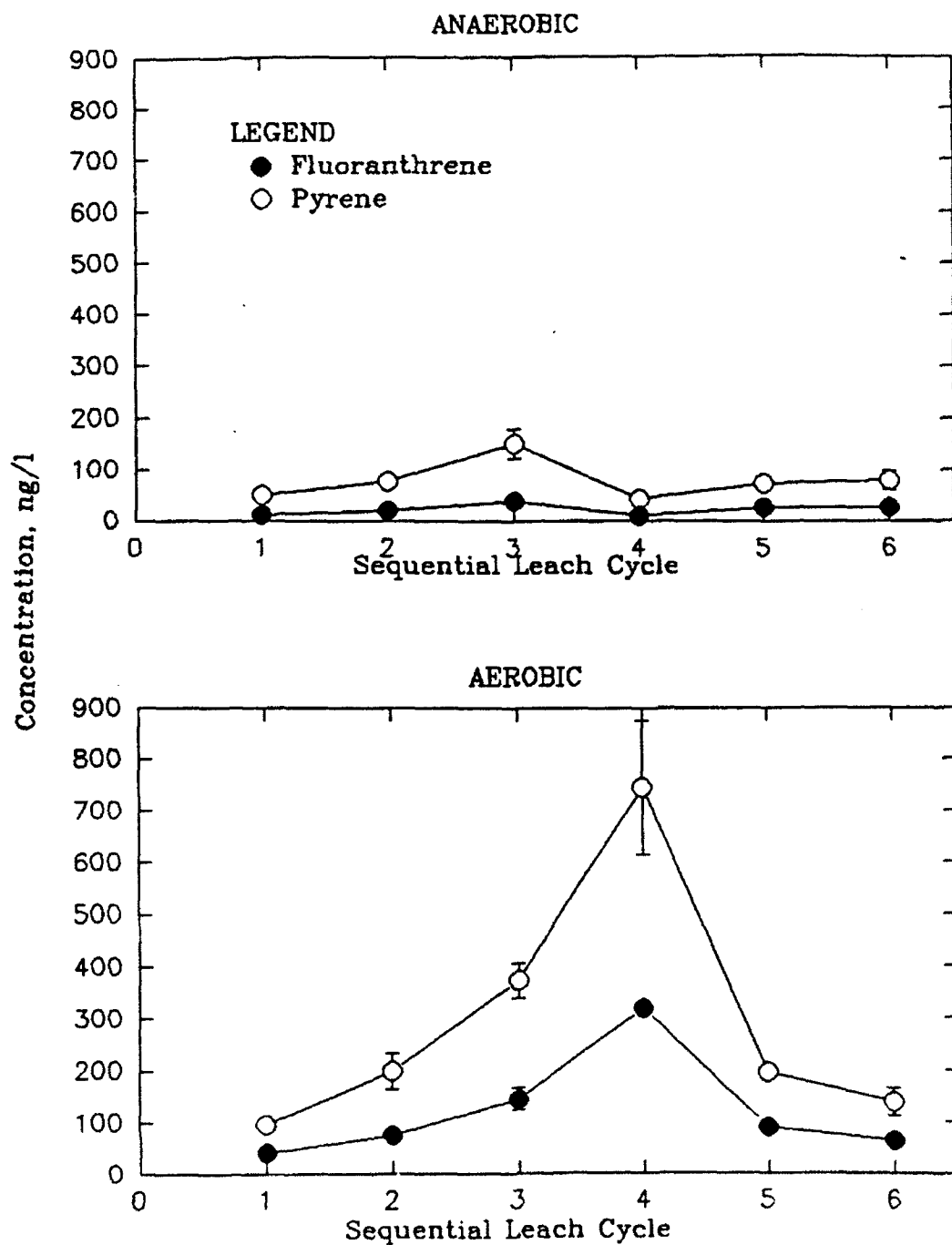


Figure V-7. Pyrene and fluoranthrene concentrations in sequential batch leachate from anaerobic and aerobic santa fe channel sediment

Table V-15

PEST Concentrations in Leachate from Anaerobic Santa Fe Channel
Sediment in Different Leach Cycles

Parameter	Leach Cycles					
	1	2	3	4	5	6
4,4-DDD	0.05(0.05)	<6.0	0.57(0.39)	0.31(0.09)	0.25(0.06)	0.55(0.33)
4,4-DDE	<0.06-6.0	<6.0	0.03(0.03)	<0.06	<0.06	<6.0
Dieldrin	<0.06-6.0	<6.0	0.05(0.05)	0.02(0.02)	<0.06	<6.0
Endrin Aldehyde	0.04(0.04)	<6.0	<0.06-6.0	<0.06	<0.06	<6.0

* Expressed in micrograms per liter (standard error in parenthesis).

Table V-16

PEST Sediment Concentrations in Anaerobic Santa Fe Channel
at Different Leach Cycles

Parameter	Leach Cycles					
	1	2	3	4	5	6
4,4-DDD	202(0.21)	202(0.21)	200(1.74)	199(1.62)	198(1.67)	196(0.87)
4,4-DDE		-- Not Detected in Sediment (<3.0-3.4)	--	--	--	--
Dieldrin	20.4(0)	20.4(0)	20.2(0.19)	20.1(0.16)	20.1(0.16)	20.1(0.16)
Endrin Aldehyde	3.54(0.16)	3.54(0.16)	3.54(0.16)	3.54(0.16)	3.54(0.16)	3.54(0.16)

* Expressed in micrograms per kilogram (standard error in parenthesis).

are presented in Tables V-17 and V-18, respectively. Peak concentrations of all pesticides detected were seen in the fourth leach cycle. Except for 4,4-DDD, the fourth leach cycle was the only time that pesticides were detected in leachate from aerobic Santa Fe Channel sediment. Concentrations of 4,4-DDD during sequential batch leaching of anaerobic and aerobic Santa Fe Channel sediment are presented in Figure V-8.

Cumulative and percentage losses of metals and butyltin

Cumulative net mass releases and percent mass losses of metals from anaerobic Santa Fe Channel sediment were either similar to or higher than releases from aerobic sediment (Table V-19), with the exception of Ag. Net mass releases of the butyltin compounds were higher under anaerobic conditions, but percent mass losses were lower because of decreased butyltin sediment concentrations following sediment oxidation (Table V-19). No losses of monobutyltin were observed under aerobic conditions because it was not detected in the sediment following six months of aerobic incubation.

Cumulative and percentage losses of PAHs and pesticides during leaching

Cumulative net mass releases of PAH compounds from Santa Fe Channel sediment were generally higher from aerobic compared to anaerobic sediments (Table V-20). Cumulative net mass PAH releases following leaching of aerobic sediment were much higher than releases from anaerobic sediment despite the lower sediment concentrations of the PAH compounds following aerobic incubation. Releases of pesticides, however, were generally higher under anaerobic conditions.

Percents of PAH compounds lost from Santa Fe Channel sediment were higher in aerobic sediment than in anaerobic sediment (Table V-20). Percents of pesticides were also generally higher under anaerobic conditions, although all the 4,4-DDD present in the aerobic Santa Fe Channel sediment was released.

Column Leaching Results

Column operating parameters

Column operating parameters are shown in Table V-21. The data in Table V-21 show that there were no substantial differences in column operating parameters for metals and organics. As previously discussed, the use of

Table V-17
PEST Concentrations in Leachate from Aerobic Santa Fe Channel
Sediment in Different Leach Cycles

Parameter	Leach Cycles					
	1	2	3	4	5	6
4,4-DDD	<0.06	<0.06	<0.06	0.75(0.43)	0.27(0.10)	0.59(0.10)
4,4-DDE	<0.06	<0.06	<0.06	0.03(0.03)	<0.06	<0.06
Dieldrin	<0.06	<0.06	<0.6	0.05(0.03)	<0.06	<0.06

* Expressed in micrograms per liter (standard error in parenthesis).

Table V-18
PEST Sediment Concentrations in Aerobic Santa Fe
Channel at Different Leach Cycles

Parameter	Leach Cycles					
	1	2	3	4	5	6
4,4-DDD	0.86(0)	0.86(0)	0.86(0)	<2.0	<2.0	<2.0
4,4-DDE	14.8(0)	14.8(0)	14.8(0)	14.7(0.11)	14.7(0.11)	14.7(0.11)
Dieldrin	--	Not Detected in Sediment (<3.4) --				

* Expressed in micrograms per kilogram (standard error in parenthesis).

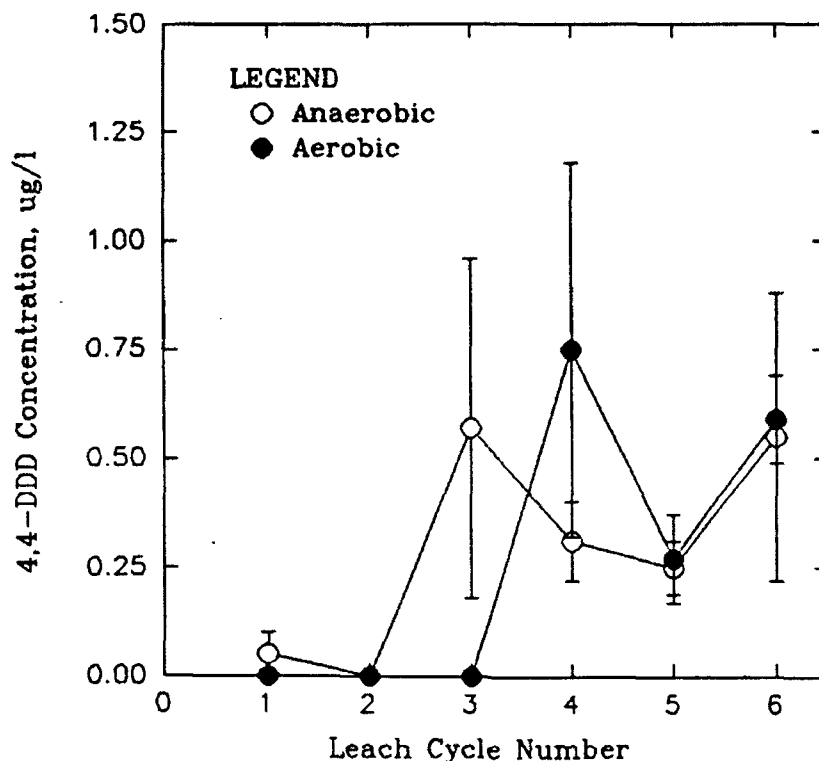


Figure V-8. 4,4-DDD Concentrations in Sequential Batch Leachate from Anaerobic and Aerobic Santa Fe Channel Sediment

separate columns for metals and organics is primarily one of convenience for collection and preservation of samples.

Column length is fixed by the column geometry and is therefore the same for all columns. Porosity, specific gravity, and water content are sediment dependent, but are the same for a given sediment. These parameters were determined on one sample collected during loading of the columns. Average pore water velocity is about the same for all the columns.

Data presentation format

Column leachate data are reported as a function of the number of pore volumes eluted from the columns. One pore volume is that volume in the sediment occupied by water. Since the columns were operated in a saturated condition, all the voids were filled by water. Figure V-9 illustrates the pore volume concept.

Table V-19

Cumulative Mass Loss (mg/Kg) of Metals and Butyltin Compounds (ug/Kg) and Percent Mass Loss from Santa Fe Channel Sediment Following 7 Cycles of Leaching for Metals and 6 Cycles of Leaching for Butyltin Compounds

<u>Parameter</u>	<u>Cumulative Mass Loss</u>		<u>Percent Mass Loss</u>	
	<u>Anaerobic</u>	<u>Aerobic</u>	<u>Anaerobic</u>	<u>Aerobic</u>
As	1.10	0.97	13.02	11.48
Zn	4.70	3.90	4.02	3.33
Cu	5.08	2.98	9.00	5.28
Ni	1.25	0.95	1.55	1.18
Cr	1.35	0.85	0.72	0.46
Ag	0.0004	0.007	0.16	2.73
Pb	1.80	1.00	6.19	3.44
Cd	0.068	0.022	9.68	3.08
Hg	0.001	0.001	0.34	0.34
Tributyltin	0.79	0.36	12.44	13.33
Dibutyltin	0.55	0.54	9.12	12.27
Monobutyltin	0.24	ND	12.00	ND

Table V-20

Cumulative Mass Loss of PAH Compounds (ug/Kg) and Pesticides (ug/Kg) and Percent Mass Loss from Santa Fe Channel Sediment Following 6 Cycles of Leaching

<u>Parameter</u>	<u>Cumulative Mass Loss</u>		<u>Percent Mass Loss</u>	
	<u>Anaerobic</u>	<u>Aerobic</u>	<u>Anaerobic</u>	<u>Aerobic</u>
Benzo(b,J,k)fluoranthene	1.07	0.50	0.17	0.21
Benzo(a)pyrene	0.43	2.50	0.14	2.67
Indeno (1,2,3-c,d)pyrene	0.10	0.40	0.06	1.50
Benzo(g,h,i)-perylene	0.23	0.50	0.10	2.27
Naphthalene	ND*	0.30	ND	4.62
Phenanthrene	0.38	0.40	0.60	1.33
Fluoranthrene	0.53	2.90	0.50	4.41
Pyrene	1.88	7.00	0.95	5.67
Benzo(a)-anthracene	0.15	1.00	0.10	2.99
Chrysene	0.13	1.00	0.08	1.39
Acenaphthylene	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND
Anthracene	0.23	0.40	0.58	2.67
Acenaphthene	ND	ND	ND	ND
4,4-DDD	6.50	0.86	3.20	100
4,4-DDT	ND	ND	ND	ND
4,4-DDE	ND	0.10	ND	ND
Dieldrin	0.37	ND	15.54	ND
Endrin Aldehyde	0.16	ND	4.32	ND

Table V-21
Column^a Operating Parameters

Column No.	Type	Contaminant			
		n	SG	w	V
7	metals	.63	2.73	0.614	1.1E-05
8	metals	.63	2.73	0.614	9.1E-06
9m	metals	.63	2.73	0.614	7.1E-06
9o	PESs	.63	2.73	0.614	1.1E-05
14	PAHs	.63	2.73	0.614	1.3E-05
15	TBTs	.63	2.76	0.614	1.2E-05

a: length equal 4 cm
n: porosity
PAHs: polyaromatic hydrocarbons
PESs: pesticides
SG: specific gravity
TBTs: butyltins
w: water content, weight of water/weight of solids
V: average pore water velocity, cm/sec

For saturated conditions, the pore volume is given by

$$P_v = A L n \quad (1)$$

where

P_v = pore volume of the sediment, cm^3
A = cross-sectional surface area of the sediment column, cm^2
L = length of the sediment column, cm
n = porosity, dimensionless

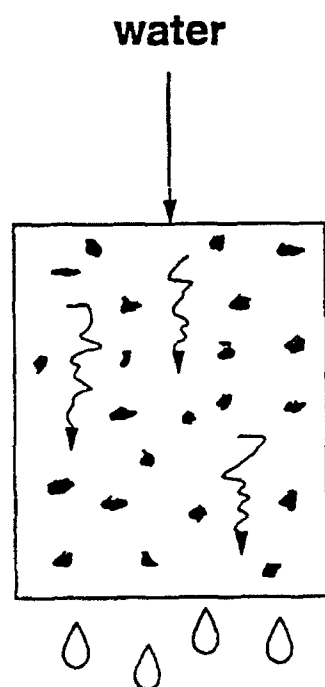
The number of pore volumes eluted is the cumulative volume of water collected divided by P_v . For the steady flow conditions maintained during column leaching, the number of pore volumes eluted is also given by

$$T = \frac{Q t}{P_v} = \frac{A V n t}{A L n} = \frac{V_d t}{L n} \quad (2)$$

where

Q = flow, cm^3/sec
T = pore volumes eluted
t = time, sec

REAL



CONCEPTUAL

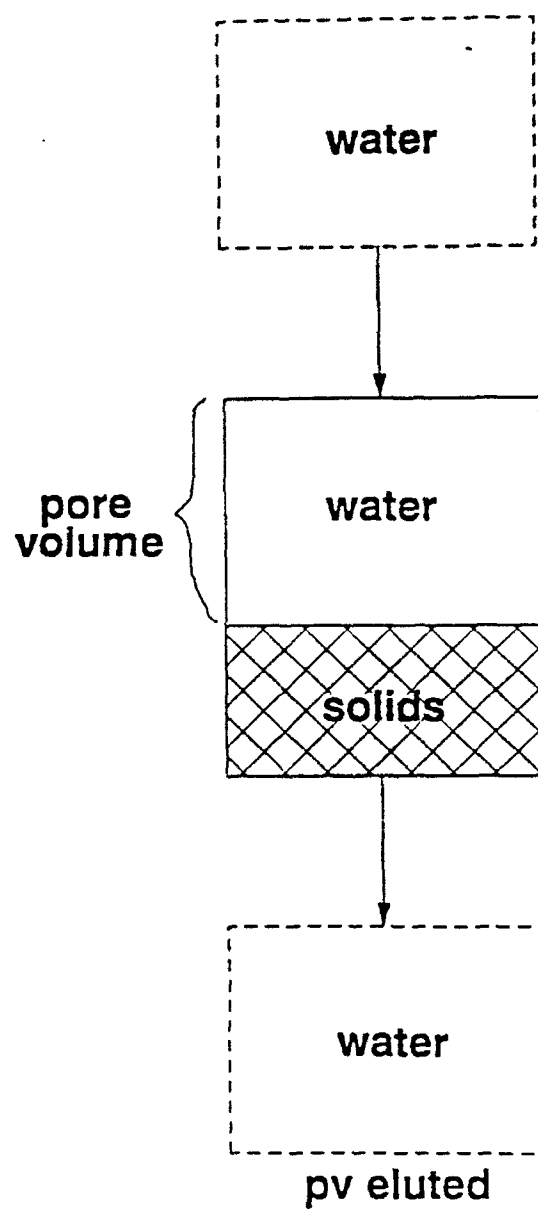


Figure V-9. Pore volume definition sketch

V = average pore water velocity, cm/sec

V_d = Darcy velocity, cm/sec

The field time for elution of one pore volume is given by

$$t' = \frac{L n}{V_d} \quad (3)$$

where t' is the time to elute one pore volume (T-1). For saturated dredged material with no standing water, the Darcy velocity is equal to the hydraulic conductivity of the dredged material. For saturated dredged material in an upland disposal facility of area A, the field elution time for one pore volume of water is given by

$$T' = \frac{A L n}{A K} = \frac{L n}{K} \quad (4)$$

where

L = depth of dredged material fill, cm

K = hydraulic conductivity, cm/sec

For example, if L = 457 cm (15 ft), K = 1 E-06 cm/sec, and n = 0.6, then the field elution time for one pore volume is about nine years.

The discussion above illustrates how to convert laboratory time for column leaching studies to an equivalent field time. Because the sediment pore volume is the basis for relating laboratory column time to field time, it is, therefore, convenient to present column elution curves as contaminant concentration versus pore volumes eluted.

General column leachate quality

Figures V-10 and V-11 show pH and electrical conductivity in column leachates. During column leaching of Santa Fe Channel sediment, pH in leachate from columns operated for testing of metals (Figure V-10) and organics (Figure V-11) was about the same as the pH of anaerobic batch leachate from Inner Oakland sediment (Table V-6). In the column tests, pH tended to increase slightly during the leaching procedure, and in the batch tests pH tended to decrease slightly. The differences, however, are too small to significantly affect metals leaching.

RICHMOND METALS

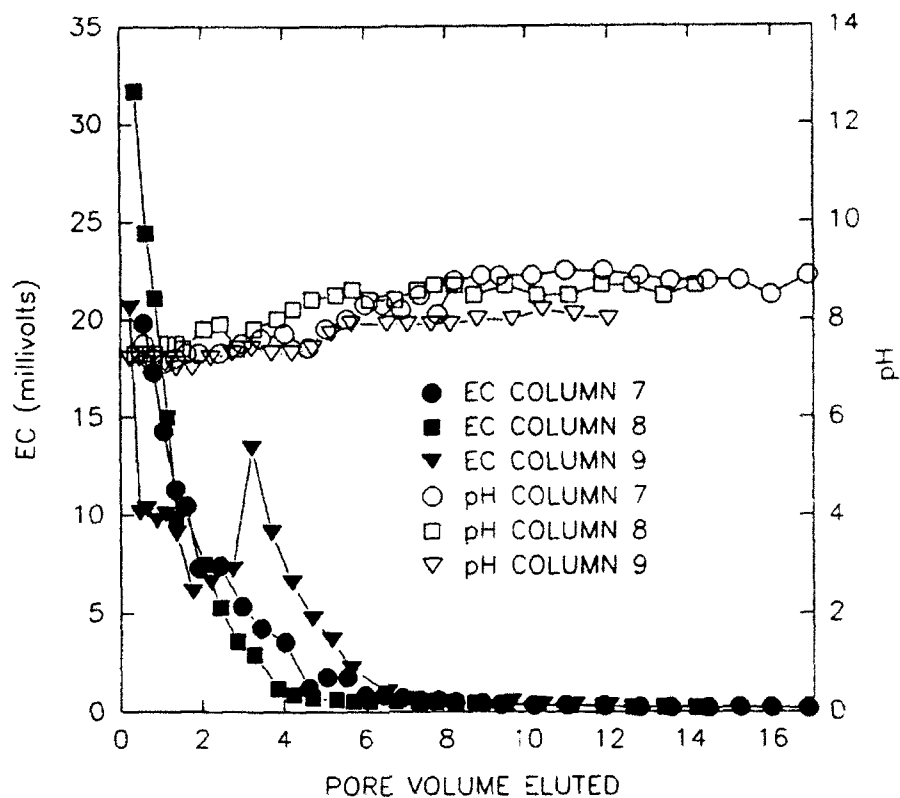


Figure V-10. Electrical conductivity and ph in column leachates collected for metals analyses

The electrical conductivity of column leachates showed classical washout curves as expected. Since electrical conductivity is a measure of dissolved salts and the estuarine sediment from Santa Fe Channel was leached with distilled-deionized water, a washout curve is expected. The electrical conductivity versus pore volumes eluted plot should monotonically decrease, that is, electrical conductivity should never increase. Column 9 (Figure V-10) showed an unexpected rise in electrical conductivity between 2 and 4 pore volumes eluted. The electrical conductivity data in Figure 11 for the columns operated for organic analysis show classical elution curves with no deviation from theory.

RICHMOND ORGANICS

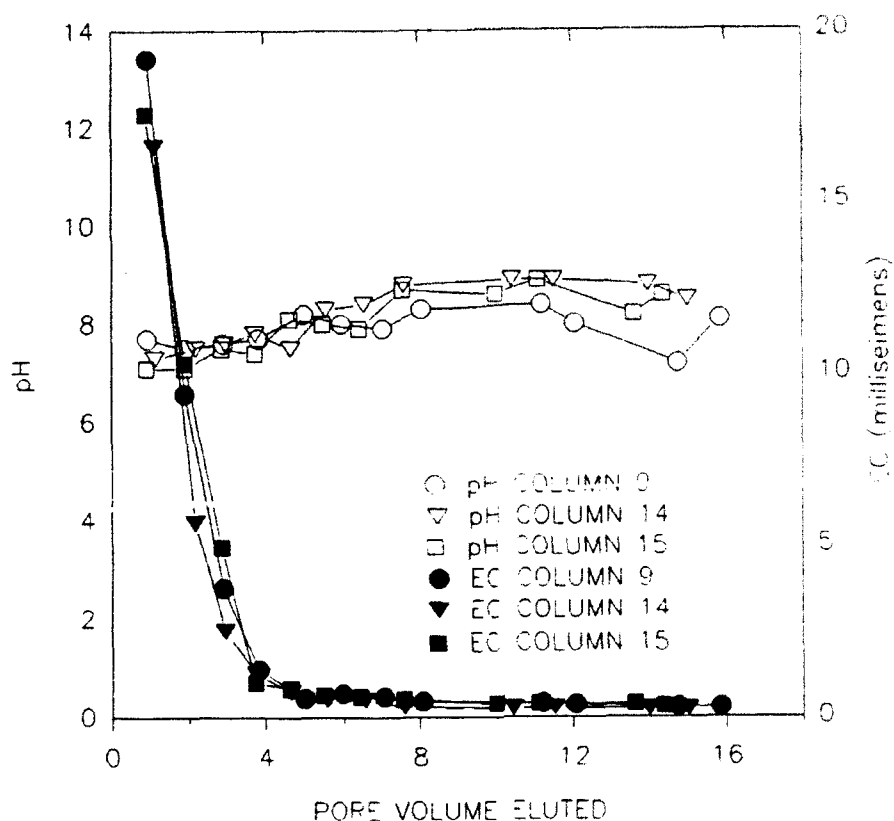
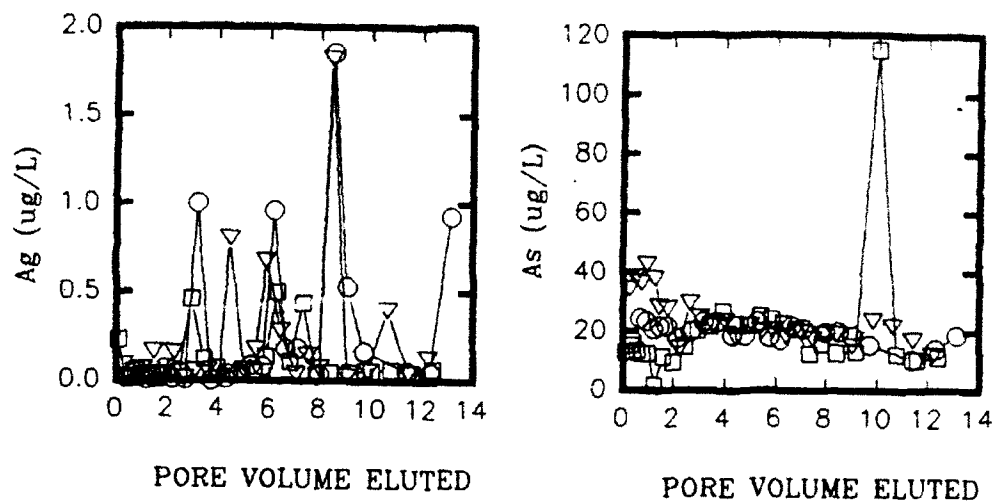


Figure V-11. Electrical conductivity and ph in column leachates collected for organic analyses

Metals in Santa Fe Channel column leachates

Metals elution curves for Santa Fe Channel sediment are shown in Figures V-12 through V-14. Metals concentrations were generally very low in column leachates. Metals concentration data from Columns 7 and 8 were generally in good agreement, but the metals concentration data from column 9 was low relative to columns 7 and 8. One exception is the arsenic elution curves where the three columns are in good agreement until at about 10 pore volumes eluted there is a high arsenic value in leachate from column 9. This value appears to be an outlier since it does not fit the overall trend in all three columns. The low concentrations in leachate from column 9 relative to column 7 and 8 indicate that some type of short-circuiting effect impacted leachate quality from column 9.

RICHMOND METALS



○ COLUMN 7
 ▼ COLUMN 8
 □ COLUMN 9

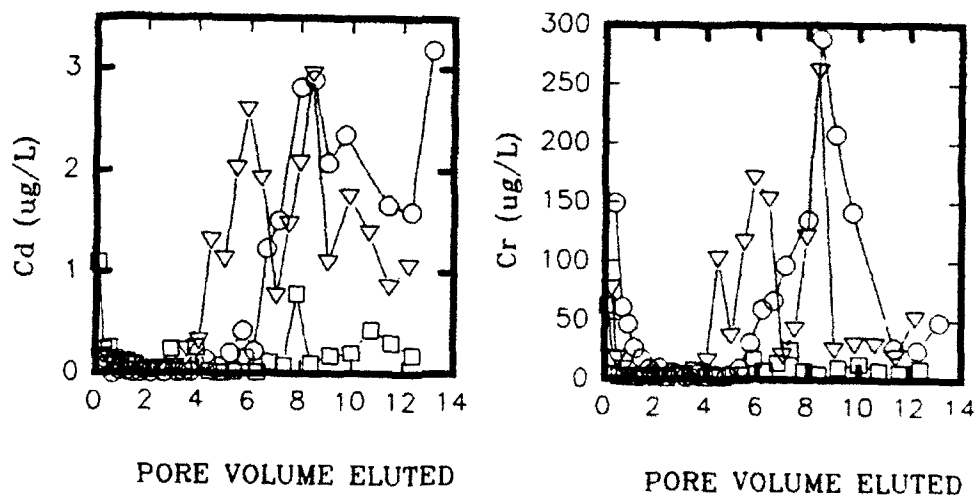


Figure V-12. Silver, arsenic, cadmium, and chromium elution curves

RICHMOND METALS

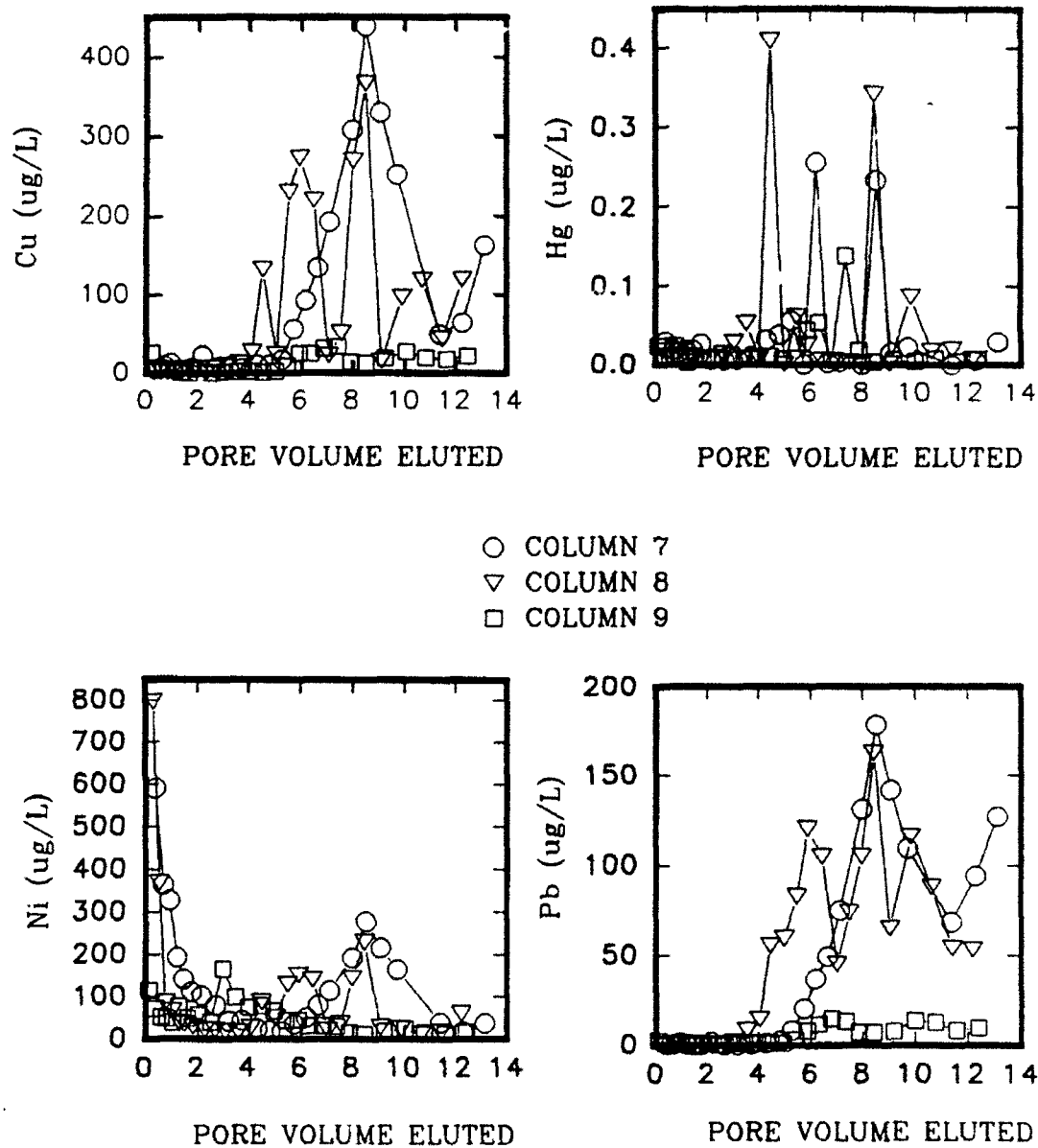


Figure V-13. Copper, mercury, nickel, and lead elution curves

RICHMOND METALS

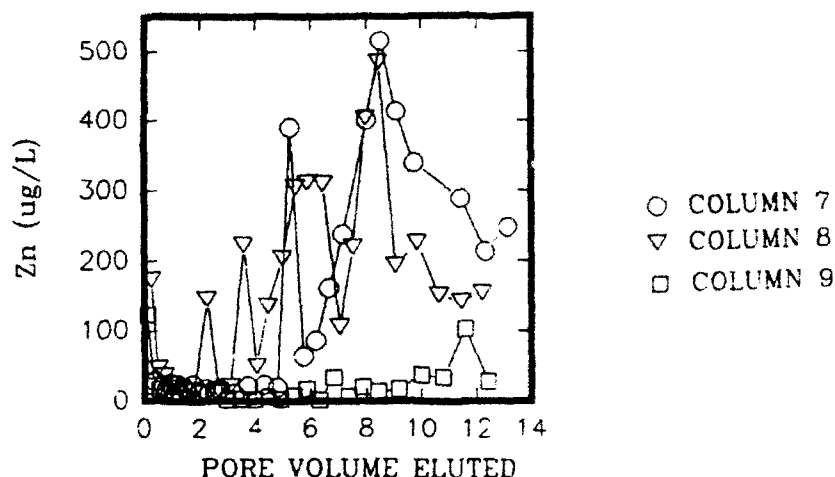


Figure V-14. Zinc elution curves

There were no distinct trends in silver elution (Figure V-12) primarily because the silver concentrations in column leachates from Santa Fe Channel sediment were so low. The highest concentration (1.8 ug/L) was measured in leachates collected from columns 7 and 8 after about 10 pore volumes were eluted. Otherwise, silver concentrations were less than 1 ug/L throughout most of the test. This type of elution curve suggests that the amount of leachable silver in Santa Fe Channel sediment is very small and leachate concentrations will tend to be less than 1 ug/L.

Arsenic (Figure V-12) which ranged from less than 1 to 119 ug/L tended to slowly decrease during column leaching except to the possible outlier previously discussed. The arsenic elution curves suggests that a reservoir of leachable arsenic resides in the sediment solids that can maintain concentrations between 10 and 30 ug/L for a long period of time.

Cadmium concentrations were initially less than 0.5 ug/L for two of the three columns. In column 9 (Figure V-12), the initial value was about 1 ug/L. In columns 7 and 8, cadmium concentrations increased after 4 pore volumes were eluted. Concentrations were still very low, however, never exceeding 3.2 ug/L. The type of elution curve shown in columns 7 and 8 for cadmium suggests that the initially very cadmium concentrations in dredged material pore water will tend to increase, but the increase will be very small.

Chromium concentrations (Figure V-12) dropped from initial values between 50 and 150 ug/L to concentrations that consistently less than the detection limit (1 ug/L). After four pore volume were eluted, chromium concentrations tended to increase in columns 7 and 8. The maximum concentration (290 ug/L) occurred at about 9.7 pore volumes eluted in column 7. Thereafter, chromium concentrations decreased and never returned to the original levels. In column 19, chromium concentrations remained low and did not show the type of increases observed in columns 7 and 8. The elution curves for columns 7 and 8 suggests that the leachable reservoirs of chromium in Santa Fe Channel sediment are initially low, increase, and then begin to decline.

Copper concentrations increased in two of the three columns. In one column (column 9, Figure V-13), very low copper concentrations were eluted throughout the test. In the other two columns, copper showed a trend for increasing concentrations between 4 and 8 pore volumes eluted and, thereafter, copper concentrations tended to decrease. Lead elution curves for Inner Oakland sediment (Figure V-13) were similar to the copper elution curves, except that the increase in lead concentrations eluted from columns 7 and 8 was more distinct than the increases in copper concentrations for these columns. The type of elution curves observed for copper and lead in columns 7 and 8 suggests that leachable reservoirs of copper and lead are initially low, then increase, and finally begin to decline.

Mercury concentrations were initially very low (Figure V-13) and then were variable between 4 and 10 pore volumes eluted. The mercury elution curves suggest very low levels of leachable mercury.

Nickel concentrations, Figure V-13, showed a rapid decrease from initial values in two of the columns. Column 7 showed a well defined peak around nine pore volumes eluted that was than the initial concentration. Column eight also showed a peak at about nine pore volumes eluted, but the peak in the elution curve for column eight was not as well defined. Nickel concentrations in leachate from column nine were low throughout the test. The type of elution curves shown in Figure V-14 for columns 7 and 8 suggests that initial nickel concentrations in dredged material pore water will be reduced by convective transport and there will be a tendency for concentrations to increase after about eight pore volumes are eluted.

Zinc elution curves (Figure V-14) were similar to the elution curves for chromium (Figure V-12). A decrease in initial concentrations was followed by an increase in concentrations that peaked around eight pore volumes eluted.

As with the other metal elution curves, column 9 showed very low zinc concentrations throughout the tests. decreased from initial values up to about 8 pore volumes eluted. The elution curves for columns 7 and 8 suggests that the initial reservoir of leachable zinc in Santa Fe Channel sediment is depleted by convective transport, but the availability of leachable zinc increases and peaks at around eight pore volumes eluted.

Butyltin in column leachates

Leachate samples from column 10 were analyzed for butyltins. Ten samples were analyzed over an experimental run involving elution of 14 pore volumes. The butyltin concentrations from these samples are provided in Table V-22. Tetrabutyltin and tributyltin were below or just above the detection limits in most samples. These data indicate no or very low release of tetrabutyltin and tributyltin during column leaching. Dibutyltin and monobutyltin releases were observed during column leaching, but there were no distinct trends in the data. Dibutyltin was the most abundant butyltin in column leachates. The range in dibutyltin concentrations was 1.7 to 24.5 ng/L, the median value was 7.1 ng/L, and the mean value was 14.2 ng/L. The range in

Table V-22
Butyltins in Column Leachates (ng/L)

<u>Pore Volume Eluted</u>	<u>Butyltin</u>			
	<u>4TBT</u>	<u>3TBT</u>	<u>DB</u>	<u>MBT</u>
0.45	<1.5	<1.7	7.1	<1.4
1.39	<1.4	<1.6	11.7	2.0
2.37	<1.2	<1.3	9.4	1.6
3.29	<1.5	<1.7	9.0	2.7
4.18	<1.4	<1.6	1.7	1.3
5.05	1.0	1.6	4.1	1.2
5.95	1.4	1.6	6.0	1.2
7.01	1.0	4.5	8.3	2.3
10.54	1.0	11.3	24.5	8.1
13.98	<8.9	<21.6	6.5	12.2

4TBT: Tetrabutyltin
3TBT: Tributyltin
DBT: Dibutyltin
MBT: Monobutyltin

monobutyltin concentrations was 1.2 to 8.1 ng/L with one value reported as less than 12.2. The median value for monobutyltin was 1.6 ng/L, and the mean value was 3.4 ng/L. These data indicate that dibutyltin and monobutyltin leach at very low concentrations, generally less than 20 ng/L for dibutyltin and less than 10 ng/L for monobutyltin.

PAHs in column leachates

PAH compounds in column leachates were below detection limits in the first two samples collected. Many of the PAH compounds, although initially below the detection limit, tended to increase after four pore volumes were eluted (Table V-23). Fluoranthene, benzo(b,j,k)fluoranthene, and pyrene elution curves shown Figure V-15 are examples of the tendency of PAH

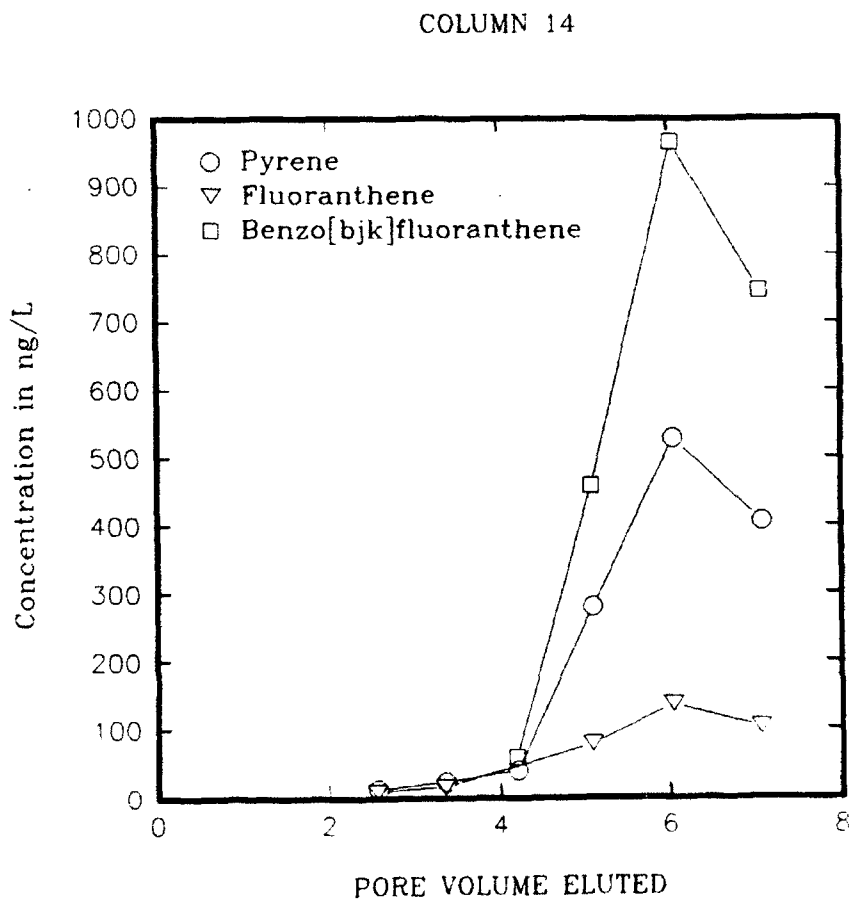


Figure V-15. Pyrene, fluoranthene, and benzo[b,j,k]fluoranthene elution curves

Table V-23

PAHs in Column Leachate (Column 14)

Parameter (ug/L)	Pore Volume Eluted							
	0.6	1.6	2.6	3.4	4.2	5.1	6.1	7.1
Naphthalene	< 7.3	< 7.3	50.1	57.8	25.5	20.7	23.5	25.7
Acenaphthylene	< 9.2	< 9.2	< 9.2	< 9.2	<18.5	<18.1	24.4	17.7
Acenaphthene	< 5.9	< 5.9	< 5.9	< 5.9	<18.5	<18.1	<16.4	<15.6
Fluorene	< 6.9	< 6.9	10.0	8.7	<18.5	<18.1	18.2	15.6
Phenanthrene	< 7.8	< 7.8	18.9	20.7	<18.5	30.3	50.0	36.5
Anthracene	<11.5	<11.5	<11.5	7.4	<18.5	27.8	55.0	39.1
Fluoranthene	< 5.9	< 3.9	6.9	13.5	<18.5	76.4	134.8	100.6
Pyrene	< 4.3	< 6.3	13.5	24.4	40.9	280.9	528.8	406.3
Benzo[a]anthracene	<30.0	<30.0	<30.0	<30.0	<18.5	28.5	65.0	49.0
Chrysene	<19.2	<19.2	<19.2	< 6.3	<18.5	48.5	82.2	63.9
Benzo[b]fluoranthene	<14.7	<14.7	<14.7	<14.3	57.3	457.8	965.2	746.0
Benzo[k]fluoranthene	<13.3	<13.3	<13.3	<10.5	NA	NA	NA	NA
Benzo[a]pyrene	< 5.4	< 6.4	< 6.4	11.9	23.3	182.2	335.9	266.5
Indeno[1,2,3-c,d]pyrene	<20.7	<20.7	<20.7	<17.3	<18.5	25.7	88.1	55.9
Dibenzo[a,h]anthracene	<21.6	<21.6	<21.6	<21.6	<18.5	<18.1	19.3	<15.6
Benzo[g,h,i]perylene	<20.0	<20.0	<20.0	<17.9	<18.5	45.9	156.6	99.9

NA - Benzofluoranthene isomers are quantified together.

concentrations to increase. Concentrations of these PAHs began to increase after 4 pore volumes were eluted, and peak concentrations occurred at about 6 pore volumes eluted. These elution curves suggest that leachable reservoirs in Santa Fe Channel sediment of fluoranthene, benzo(b,j,k)fluoranthene and pyrene and several other PAHs that showed similar elution curves were initially low and then increased.

Pesticides in column leachates

Pesticides were generally below the detection limits in column leachates (Table V-24). Nineteen pesticides were analyzed in eight column leachate samples for a total of 152 analyses. Only nine values were above detection limits. The pesticides present in concentrations above the detection limits were dieldrin, 4,4'-DDE, and 4,4'-DDD. Concentrations of these pesticides in column leachates collected before four pore volumes were eluted were below the detection limit. The detectable concentrations of dieldrin and 4,4'-DDE were very low, less than 0.22 ug/L. The pesticide 4,4'-DDD showed a distinct trend for increasing concentrations toward the end of the column leach test. In the last two samples collected, 4,4'-DDD was present at 1.1 ug/L. These column leachate data for pesticides suggest that most pesticides do not leach from Santa Fe Channel sediment. Dieldrin, 4,4'-DDE, and 4,4'-DDD pesticides are exceptions.

Discussion

Sequential batch leach data

Sequential batch leaching of both anaerobic and aerobic Santa Fe Channel sediment did not follow classical desorption theory. The appearance of peaks in the leachate concentration data indicated nonconstant sediment geochemistry and nonconstant distribution coefficients during leaching. If constant distribution coefficients existed, contaminant concentrations would have decreased during sequential batch leaching. If constant distribution coefficients existed, contaminant concentrations would have decreased during sequential batch leaching. The changes in sediment geochemistry are reflected in the changes in conductivity and pH during sequential leaching.

The nonconstant partitioning evident in the sequential batch leach data for Santa Fe Channel sediment has been observed in previous leaching studies on estuarine sediments (Myers and Brannon 1988, Palermo et al. 1989). Nonconstant partitioning means that distribution coefficients change as the solid

Table V-24
Pesticides in Column Leachate (Column 9)

Parameter (ug/L)	Pore Volume Eluted					
	0.46	1.41	2.39	3.36	4.41	5.47
A-BHC	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
B-BHC	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
D-BHC	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Lindan	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Heptachlor	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Aldrin	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Heptachlor Epoxide	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Endosulfan I	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Deldrin	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
4,4' -DDE	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Endrin	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Endosulfan II	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
4,4' -DDD	<0.06	<0.06	<0.06	<0.06	<0.12	<0.55
Endosulfan Sulfate	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
4,4' -DDT	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Methoxychlor	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
Endrin Ketone	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Alpachlordane	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Toxaphene	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06

phase concentration decreases during sequential leaching until a turning point is reached (Figure V-16). The nonconstant portion of the desorption isotherm shown in Figure V-16 is related to elution of salt. As salt is eluted, the ionic strength of the aqueous phase is reduced. Decreasing ionic strength increases repulsive forces between colloids so that flocculated colloidal matter becomes dispersed in the water phase. Sediment colloids that become dispersed in the water phase can carry contaminants and increase the apparent dissolved concentration of these contaminants (Brannon et al. 1991). Thus, deflocculation of sediment colloids is probably the process responsible for nonconstant partitioning.

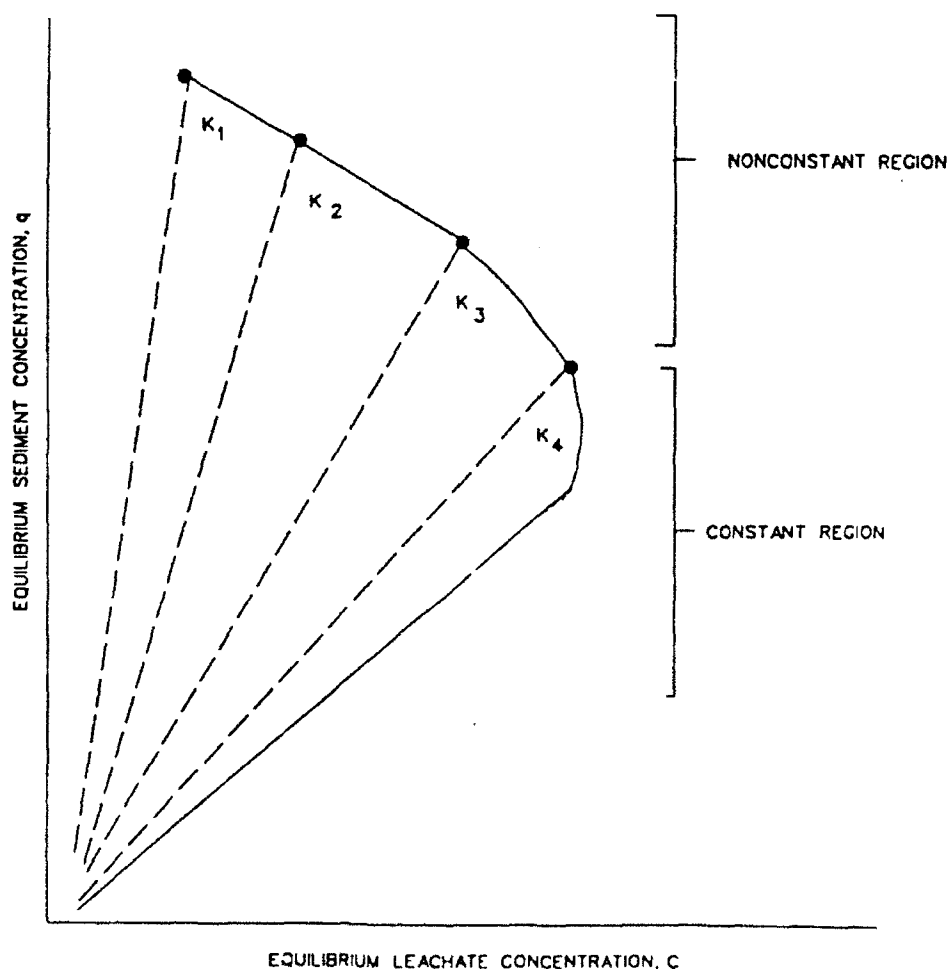


Figure V-16. Desorption isotherm illustrating and constant partitioning

Anaerobic isotherms

Figure V-17 shows desorption isotherm plots for arsenic, copper, dibutyltin, and pyrene for anaerobic Santa Fe Channel sediment. The points in these figures are sediment contaminant concentration-leachate contaminant concentration pairs from the sequential batch leach data. Thus, the seven points in Figure V-17 for As and Cu and the six points for dibutyltin and pyrene represent the seven or six cycles in the sequential batch leach test. The highest point relative to the vertical axis is the data pair from the first cycle, the second highest point relative to the vertical axis is the data pair from the second cycle, and so forth. Figure V-18 shows the type of isotherm obtained when the distribution coefficient is constant. The nonconstant partitioning clearly evident in Figure V-17 was observed for most of the contaminants investigated in this study.

Aerobic data

Santa Fe Channel sediment showed only a one unit decrease in pH following oxidation. This lack of change in pH was reflected in the leaching results. Anaerobic leaching of metals, butyltin compounds, and pesticides was either higher than or equal to leaching under aerobic conditions. Oxidation of Santa Fe Channel sediment, however, resulted in increased leaching of most PAH compounds compared to anaerobic sediment (Table V-20). The increase in PAH leaching was substantial, and indicating that PAH leachate concentrations will be higher if dredged material in an upland facility is drained to the extent that oxidizing conditions exist throughout the dredged material. From a management perspective, these results indicate that PAH mobility can be reduced by maintaining anaerobic conditions.

Comparison of Sequential Batch and Column Leach Data

Anaerobic sequential batch and column tests were in good qualitative agreement for most contaminants in Santa Fe Channel sediment. Initial contaminant concentrations in column leachates tended to be higher than leachate concentrations from the first cycle of the sequential batch leach test. Peaks in batch leachate data indicating nonconstant sediment geochemistry and nonconstant distribution coefficients were confirmed as increasing contaminant concentrations in column leachate. Specific comparisons are provided below.

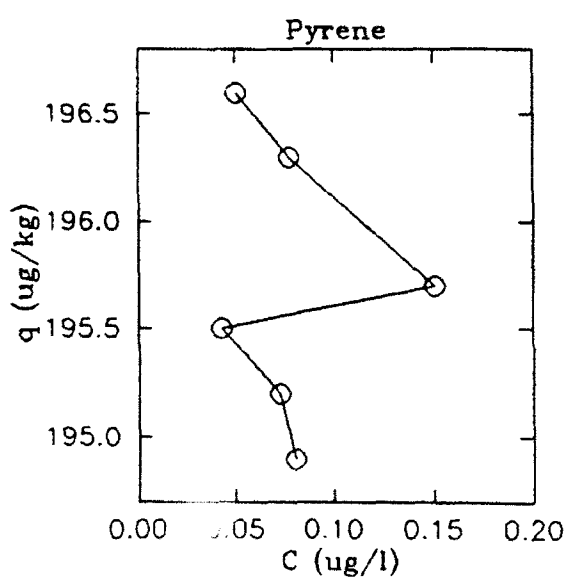
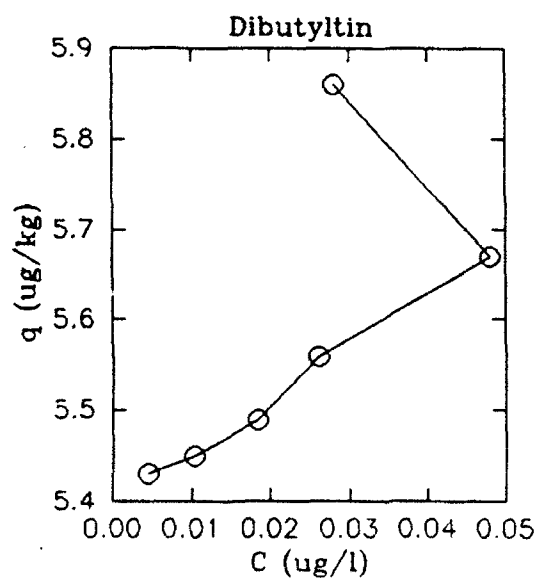
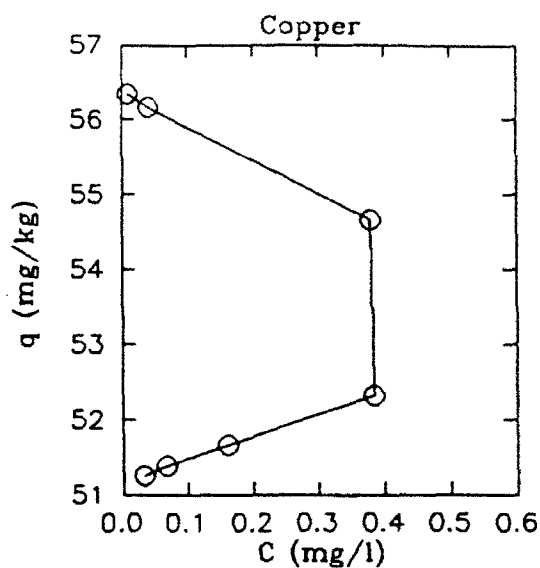
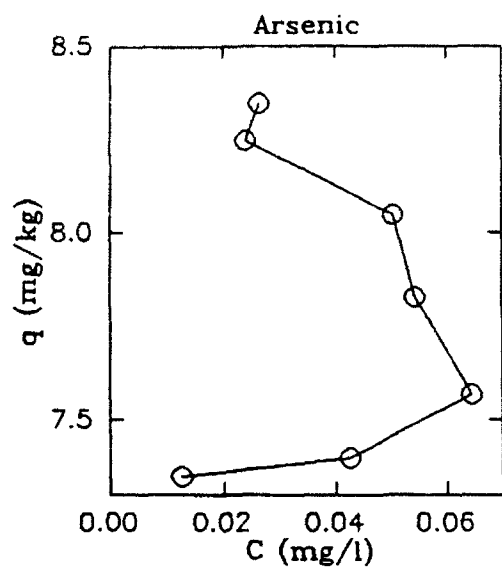


Figure V-17. Desorption isotherm for As, Cu, dibutyltin, and pyrene from anaerobic Santa Fe channel sediment

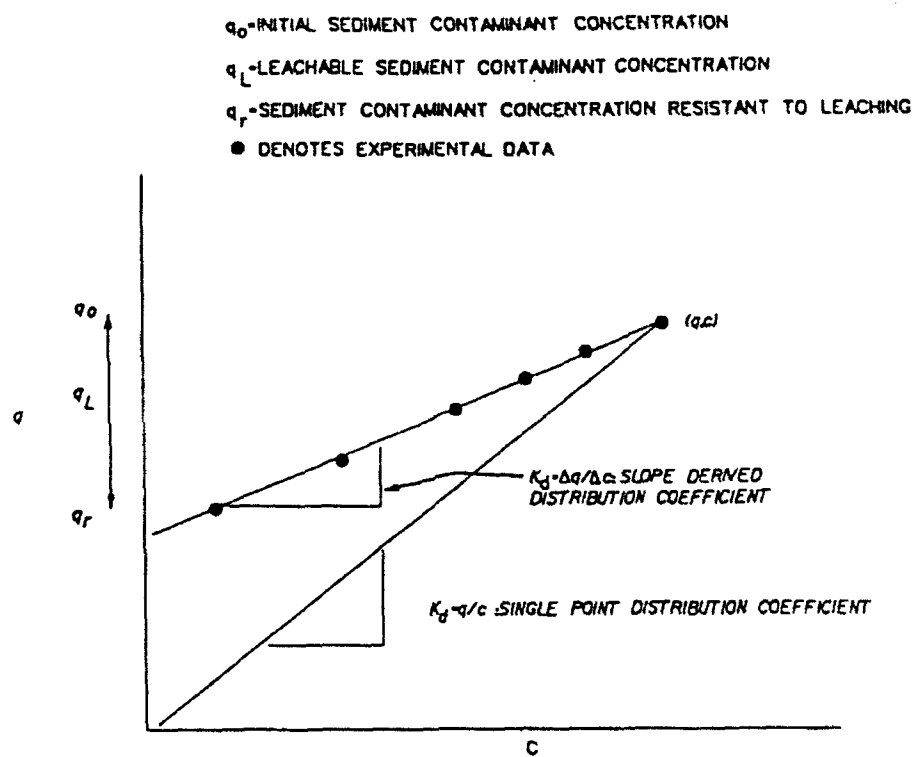


Figure V-18. Desorption isotherm illustrating constant partitioning

Silver

Silver concentrations in column leachates were higher than in leachate from the anaerobic sequential batch test. The maximum concentration in the column test was 1.8 ug/L while the maximum concentration in the anaerobic sequential batch test was only 0.14 ug/L. Concentrations in the column tests also tended to be more variable than those in the batch test. The absence of distinct trends during batch testing occurred during column testing.

Arsenic

Arsenic concentrations in column leachates were similar to concentrations in leachates from the anaerobic sequential batch test. The trend of increasing concentrations observed during batch testing was not observed during column testing. After the first two cycles in the batch test, batch arsenic concentrations tended to be slightly higher than the column arsenic concentrations. With the exception of one outlier in the column data, the maximum arsenic concentration (64.4 ug/L) occurred in the batch test.

Cadmium

Cadmium concentrations in column leachates were similar to the concentration in leachates from the anaerobic sequential batch leach test. The tendency for cadmium concentrations to increase during anaerobic sequential batch leaching was confirmed in the column test. The maximum cadmium concentration (5.5 ug/L) occurred in the batch test.

Chromium

Initial concentrations of chromium from the columns were higher than those in the batch tests. Increasing Cr concentrations observed in the batch tests were confirmed during column testing. The maximum concentration (290 ug/L) occurred in the column test.

Copper

Copper concentrations in column and anaerobic sequential batch leachates were in good agreement throughout both tests. Copper concentrations were initially less than 10 ug/L and increased to concentrations around 500 ug/L in both tests. The maximum concentration (584 ug/L) occurred in the column test.

Mercury

Mercury concentrations in column leachates and anaerobic sequential batch leachates were in good agreement. The trend for very low concentrations to increase during anaerobic sequential batch leaching was confirmed in column tests. The maximum concentration (0.41 ug/L) occurred in the column test.

Nickel

Nickel concentrations in column leachates were higher than those in the anaerobic sequential batch test. Increasing nickel concentrations observed during batch testing were evident during column testing but initial concentrations in column leachates were much higher than those in the peak that developed after several pore volumes were eluted. The maximum concentration (800 ug/L) occurred in the column test.

Lead

Lead concentrations in column leachates and anaerobic sequential batch leachates were in good agreement. Increasing lead concentrations observed in batch testing was confirmed in the column test. Even the peak values were similar. The maximum concentration (193 ug/L) was observed in the batch test.

Zinc

Zinc concentration column leachates and anaerobic sequential batch leachates were in good agreement. Increasing Zinc concentrations observed in the batch tests was confirmed during column testing. Peak values were similar. The maximum value (527 ug/L) was observed in the batch test.

Butyltins

Mono- and dibutyltin concentrations in column leachates were somewhat lower than mono- and dibutyltin concentrations in batch leach tests. Neither test showed well-defined trends. The maximum mono- and dibutyltin concentrations (17.9 and 48.8 ng/L, respectively) occurred in the batch test. Tributyltin concentrations were substantially lower in the column test than in the batch test. The tendency for tributyltin concentrations to increase in the batch test was also evident in the column test. The maximum tributyltin concentration (67.4 ng/L) occurred in the batch test. Tetrabutyltin concentrations were generally near or below the detection limit in column and batch leachates.

PAHs

Comparison of PAHs in batch and column leach tests for Santa Fe Channel sediment indicates four general categories: PAHs that were below or near the detection limit in both batch and column leachates, PAHs that were generally above the detection limit but showed no distinct trends in either the batch or column test, PAHs that showed decreasing trends in the batch test and increasing trends in the column test, and PAHs for which increasing concentrations were observed in batch and column tests. The fourth category was the largest category. PAH compounds in the first category were acenaphthylene,

acenaphthene, fluorene, and dibenzo(a,h)-anthracene. Anthracene was the only PAH compound in the second category. PAH compounds in the third category were naphthalene and phenanthrene. PAH compounds in the fourth category are listed in Table V-25. Also shown in Table V-25 are maximum PAH concentrations in batch and column leachates. The tendency for increasing concentrations of these PAH compounds during anaerobic sequential batch leaching was confirmed in the column test, although the maximum concentrations in column leachate was substantially higher than the maximum concentrations in batch leachate.

Table V-25
Maximum Concentrations (ng/L) for PAH Compounds Showing
Tendency to Increase in Batch and Column Leach Tests

<u>PAH Compound</u>	<u>Maximum Concentrations</u>	
	<u>Batch Test</u>	<u>Column Test</u>
Fluoranthene	39.5	134.8
Pyrene	151	528
Benzo[a]anthracene	16.8	65
Chrysene	12.6	82.2
Benzo[b,j,k]fluoranthene	81.1	965.2
Benzo[a]pyrene	37.5	336
Indeno[1,2,3-c,d]pyrene	26.1	55.9
Benzo[g,h,i]perylene	48.0	156

Pesticides

Batch and column leachate data were in good agreement qualitatively and quantitatively for pesticides. The pesticides that were below the detection limit in the batch test were also below the detection limit in the column test. The pesticide leached in the largest amounts was 4,4'-DDD in both batch and column tests. The increasing tendency for this pesticide in the batch test was confirmed in the column test. Maximum concentrations in batch and column tests agreed within a factor of 2.

Integrated Approach

As discussed in the preceding section, there is qualitative agreement between batch and column leach test for most of the contaminants in Santa Fe Channel sediment. When the batch data indicate nonconstant partitioning with

peak contaminant concentrations occurring after several cycles of leaching, the column tests generally show increases in contaminant concentrations after several pore volumes have been eluted. In this section, the extent to which batch and column leach tests quantitatively agree is discussed.

An integrated approach (Figure V-19) involving predicted and observed column elution curves is used to make quantitative comparisons. In the

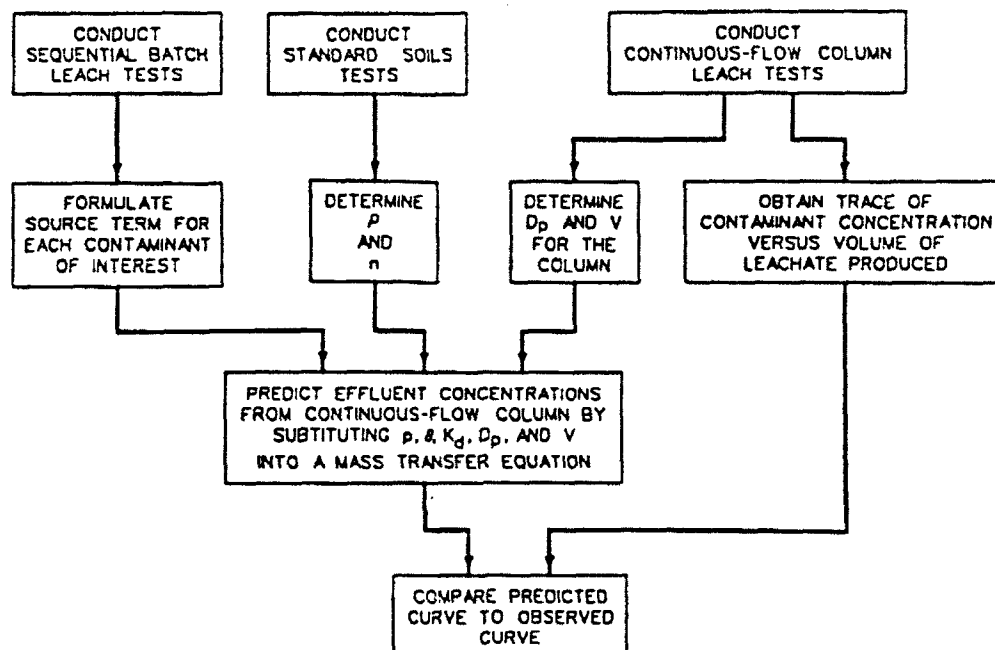


Figure V-19. Integrated approach for examining the source term

integrated approach, information from sequential batch leach tests, soils tests, and column operation conditions are used in a contaminant transport equation to predict column elution histories. The one-dimensional contaminant transport equation for steady-flow, saturated columns on which the integrated approach is based is given below (Hill, Myers, and Brannon 1988).

$$D_p \frac{\partial^2 C_1}{\partial z^2} - V \frac{\partial C_1}{\partial z} + S = \frac{\partial C_1}{\partial t} \quad (5)$$

$$S = \frac{\rho_b}{n} \frac{\partial q_i}{\partial t} \quad (6)$$

where

D_p - dispersion coefficient for i^{th} contaminant, cm^2/sec

C_i - pore water concentration of i^{th} contaminant, mg/L

z - distance from water entrance to sediment column, cm

V - average pore water velocity, cm/sec

t - time, sec

S - interphase contaminant transfer, mg/L sec

ρ_b - bulk density, kg/L

n - porosity, dimensionless

q_i - solid phase concentration of i^{th} contaminant, mg/kg

Full implementation of the integrated approach to leaching of contaminants from estuarine sediments has not been possible because a mathematical formulation of the interphase contaminant transfer term (S) for nonconstant partitioning has not been available (Myers and Brannon 1988; Palermo et al. 1989). Development of a complete mix equation with a source term formulation that captures the main features of nonconstant partitioning and application of this equation to Santa Fe Channel sediment are described below.

Application of the local equilibrium assumption to dredged material (Myers, Brannon, and Price 1992) yields

$$q = K_d C \quad (7)$$

where K_d is the equilibrium distribution coefficient, L/kg , and is contaminant and sediment specific. Taking the derivative with respect to time and assuming K_d is a constant yields

$$\frac{\partial q}{\partial t} = - \frac{\partial [K_d C]}{\partial t} = - K_d \frac{\partial C}{\partial t} \quad (8)$$

Contaminant transport equations based on equations 7 and 8 are available and have been applied to leaching of freshwater sediments (Environmental

Laboratory 1987). These models predict elution curves that monotonically decrease and, therefore, are not applicable to estuarine sediments for which contaminant concentrations do not monotonically decrease in either batch or column leach tests.

For nonconstant K_d , equation 7 is written as

$$q = K_d(T) C \quad (9)$$

where $K_d(T)$ is some function of T , the number of pore volumes eluted. Since the nonconstant characteristic of K_d is related to salt elution (Branon et al. 1991) and salt elution is a decaying exponential, $K_d(T)$ is written as

$$K_d(T) = K_d^f + (K_d^o - K_d^f) \exp(-\beta T) \quad (10)$$

where

K_d^o - initial distribution coefficient, that is, before salt has been washed out, L/kg

K_d^f - freshwater distribution coefficient, that is, after salt has been washed out, L/kg

β - empirical coefficient, dimensionless.

Substituting into equation 9 from equation 10 for $K_d(T)$ and taking the derivative with respect to T yields

$$\frac{dq}{dT} = C\beta(K_d^o - K_d^f) - \left[K_d^f + (K_d^o - K_d^f) \exp(-\beta T) \right] \frac{dC}{dT} \quad (11)$$

Through the proper change of variable, dq/dT as given in equation 11 can be substituted into equation 6 and then into equation 5. The result, however, is a partial differential equation for which there are no published solutions. The equation could be solved numerically, but development of a numerical model for nonconstant partitioning was beyond the scope of this study. Instead, a complete mix equation was developed that includes nonconstant partitioning but

neglects spatially dependent convective and dispersive effects. The complete mix equation is

$$-C + \frac{\rho_b}{n} \frac{dq}{dT} = \frac{dC}{dT} \quad (12)$$

Substituting from equation 11 for dq/dT yields

$$\frac{dC}{dT} = \left[\frac{\left[\frac{\beta \rho_b (K_d^o - K_d^f)}{n} \right] \text{EXP}(-\beta T) - 1}{1 + \frac{\rho_b}{n} [K_d^f + (K_d^o - K_d^f) \text{EXP}(-\beta T)]} \right] C \quad (13)$$

For the initial condition of $C(0)=C_o$, the solution of equation 13 is

$$C(T) = C_o \text{EXP} \left[\left[\frac{A}{\beta D} + \frac{1}{\beta B} \right] \ln(B+D) - \frac{T}{B} - \left[\frac{A}{\beta D} + \frac{1}{\beta B} \right] \ln(B + D \text{EXP}(-\beta T)) \right] \quad (14)$$

where

$$A = \beta \rho_b (K_d^o - K_d^f)/n$$

$$B = 1 + (\rho_b K_d^f)/n$$

$$D = \rho_b (K_d^o - K_d^f)/n$$

Setting equation 13 equal to zero yields

$$T_p = \left[-\frac{1}{\beta} \right] \ln \left[\frac{n}{\beta \rho_b (K_d^o - K_d^f)} \right] \quad (15)$$

where

T_p = number of pore volumes eluted to reach the peak concentration

Model parameters for selected contaminants in Santa Fe Channel sediment are presented in Table V-26. Also presented in Table V-26 are T_p values predicted by equation 15. Model parameters were obtained by analyzing

Table V-26

Model Parameters and Predicted Number of Pore Volumes Needed to Reach
Peak Concentrations for Selected Contaminants in
Santa Fe Channel Sediment

<u>Sediment/Metal</u>	<u>K_d^o</u>	<u>K_d^f</u>	<u>β</u>	<u>T_p</u>
Arsenic	107	12.5	0.125	24
Cadmium	281	5.7	0.285	17
Copper	280	5.0	0.277	17
Lead	1228	2.4	0.330	20
Silver	76	9.5	0.147	19
Pyrene	6893	1296	0.190	39
Fluoranthene	13251	2653	0.180	45
Benzo[b,j,k]fluoranthene	25421	7705	1.57	6.8

contaminant desorption isotherms obtained from the anaerobic sequential batch leach data. Desorption isotherm analysis involved finding slopes and intercepts and judgement as to what portions of the isotherms to include in the analysis. For some contaminants, the desorption isotherms were not well-defined, so that, model parameters could not be obtained.

Comparison of Figures V-12 - V-15 with the predicted T_p values in Table V-26 shows that when equation 15 is used with coefficients obtained from batch data the number of column pore volumes required for appearance of peak concentrations is overestimated. Benzo[b,j,k]fluoranthene was the only exception.

Predicted and observed elution curves are shown in Figure V-20 for cadmium and copper. The predicted curves are based on equation 14 and model parameters listed in Table V-26. Predicted and observed elution curves for cadmium and copper were selected for discussion because these elution curves represent the range of agreement between predicted and observed elution curves for other contaminants. Figure V-20 shows that the complete mix model with nonconstant equilibrium partitioning simulates the rising limb of the cadmium elution curve. The predicted cadmium curve represents about the best the model equation can do using batch coefficients. Figure V-20 shows that the predicted curve for copper does not rise high enough nor does it rise rapidly enough. This disparity between predicted and observed copper elution curves occurs for other contaminants also. Figure V-20 also shows that the column

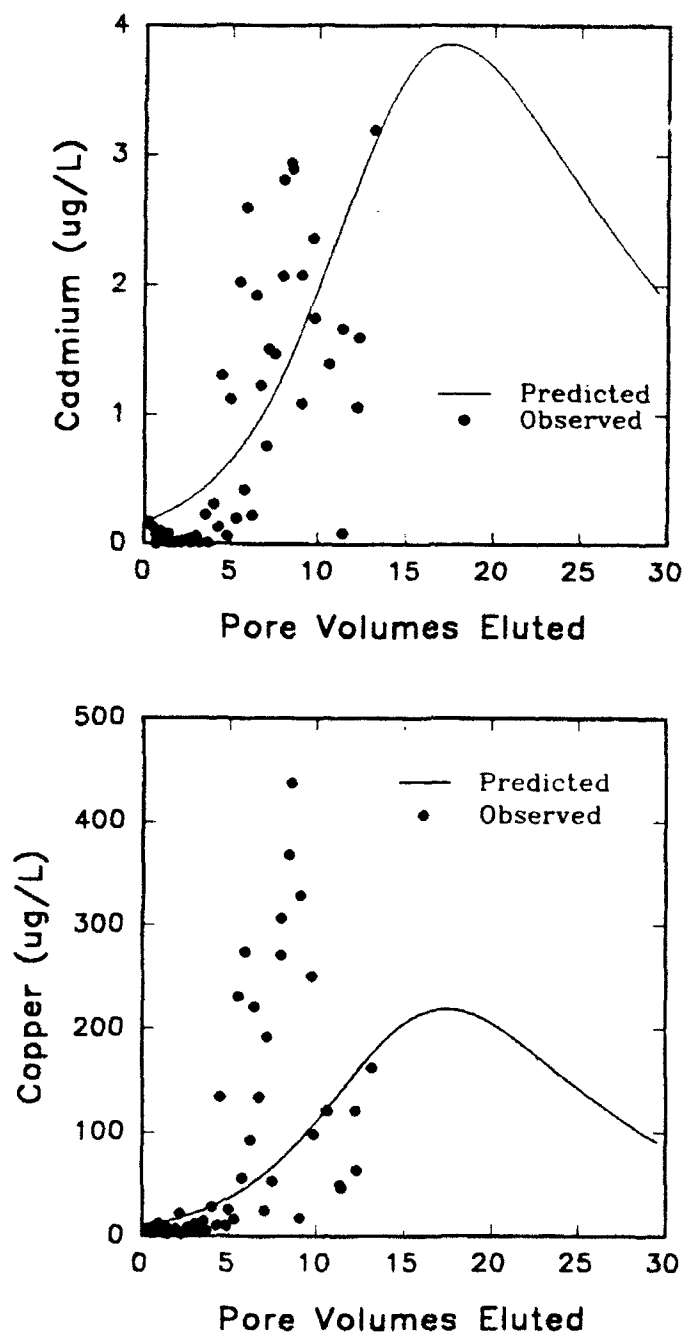


Figure V-20. Predicted and observed elution curves for cadmium and copper

leaching studies were not conducted long enough to clearly define the location and shape of the peak on the elution curve.

Equation 14, however, is able to simulate the type of leaching trends observed in the batch tests, that is, increasing concentrations, followed by decreasing concentrations. Equation 14 may, therefore, provide a starting point for modeling nonconstant partitioning in estuarine sediments. The model, however, tends to overestimate the location of peak values on the elution curves for Santa Fe Channel sediment. A better fit for the model could be obtained by finding column best fit parameters, but the emphasis in this study was on testing the application of parameters obtained from batch data. A solution (analytical or numerical) for equation 5 with the formulation for nonconstant partitioning given in equation 14 is needed to fully test the adequacy of the formulation.

Leachate Impacts and Controls

Leachate from dredged material placed in a disposal site is produced by three potential sources: the original pore water, or interstitial water from the dredged material, net movement of precipitation through the dredged material, and, for nearshore sites, ground water or estuary water contacting the dredged material as a result of tidal pumping. A confined disposal facility (CDF) adjoining a waterway may be affected by tidal pumping if the CDF walls are permeable. For this analysis, the assumption was made that CDFs will be sited in an upland location where tidal pumping is not a factor.

Leachate generation in a CDF depends on dredged material hydraulic conductivity, initial water content, and local hydrology. After filling, dredged material in a CDF is initially saturated (all voids are filled with water). As evaporation and seepage removes water from the voids, the amount of water stored and available for gravity drainage decreases. After some time, usually several years, a quasi-equilibrium is reached in which water that seeps or evaporates is replenished by infiltration through the surface. The amount of water stored when a quasi-equilibrium is reached and the amount of water released before a quasi-equilibrium is reached is highly dependent on local hydrology, dredged material properties, and facility design factors. To predict time-varying leachate flow, all these factors must be considered.

Preproject estimation of leachate flow, therefore, requires coupled simulation of local weather patterns and surface and subsurface processes

governing leachate generation. Important climatic processes and factors include precipitation, temperature, and humidity. Important surface processes include infiltration, snowmelt, runoff, and evaporation. Important subsurface processes include evaporation from dredged material voids and flow in unsaturated and saturated zones. The Hydrologic Evaluation of Landfill Performance (HELP) model (Schroeder et al. 1988) was used to simulate these processes for selected CDF designs for Inner and Outer Oakland sediments. HELP is a hydrologic water budget model that accounts for the effects of surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, lateral drainage to leachate collection systems, and percolation through liners.

Three alternative scenarios were selected to demonstrate use of the HELP model for estimation of percolation rates and to compare control measures for a CDF. Scenarios for CDF alternatives with 3-ft and 12-ft (with and without liners) depths were investigated. The volume of dredged material after disposal is assumed to be 1.5 million cubic yards for all three alternatives. The alternatives are described as follows:

- a. Scenario A. This scenario involves disposal of Santa Fe Channel sediment in a CDF with no controls, other than routine management of the surface to provide for drainage of surface runoff. Fill depth is 3-ft and the surface area is 310 acres.
- b. Scenario B. Scenario B is the same as scenario A except that dredged material depth is 12-ft and the surface area is 77.5 acres.
- c. Scenario C. This scenario introduces a composite liner to reduce the amount of leachate percolating through the bottom of the CDF for scenario B. The liner consists of a 1 ft thick barrier soil with a hydraulic conductivity of $1 \text{ E-}07 \text{ cm/sec}$ and a flexible membrane liner.

HELP model runs for each of these scenarios used the same basic parameters. Climatic data were generated for a ten year period by the model, based on historical climatic data for the San Francisco area. A Soil Conservation Service runoff curve number of 88 was used. The surface of the CDF was assumed to be devoid of vegetation. Dredged material was assumed to be saturated. Hydraulic conductivity was estimated to be $2 \text{ E-}07 \text{ cm/sec}$. This estimate is based on engineering data for Inner and Outer Oakland sediments (Lee et al. 1993). Hydraulic conductivity as a function of void ratio is shown in Figure V-21 for Inner and Outer Oakland sediments. The void ratio of Santa Fe Channel sediment is 1.73. For this void ratio, Figure V-21 suggests a hydraulic conductivity of $2 \text{ E-}07 \text{ cm/sec}$. Because field hydraulic

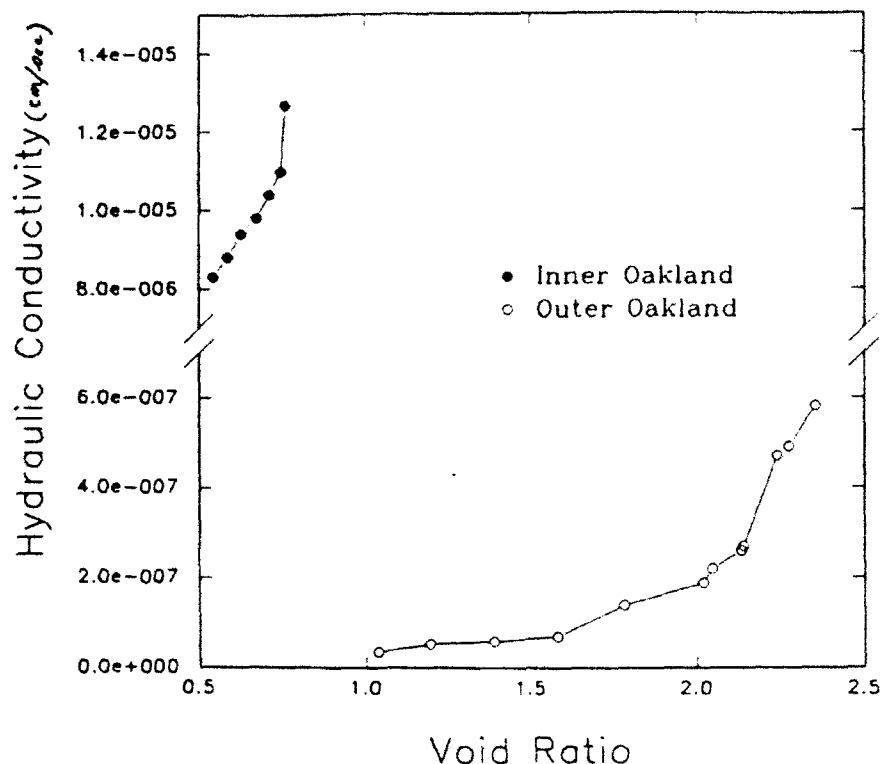


Figure V-21. Hydraulic Conductivity versus Void Ratio for Santa Fe Channel Sediments (from Lee et al. 1992)

conductivity can be higher than laboratory measurements indicate, the HELP model runs were conducted using 2 E-06 cm/sec as the hydraulic conductivity. Since dredged material placed in a disposal site will consolidate and develop lower void ratios with time, a value ten times the initial hydraulic conductivity is a reasonable upper bound for long term simulations.

Table V-27 lists annual percolation into foundation soils for scenarios A-C for a ten year simulation period. The high rates during the early years are a result of drainage of pore water with the material when initially placed in the site. By the tenth year, percolation becomes steady for all three scenarios. Scenario A has the highest initial percolation rates, and scenario C has the lowest initial and overall percolation rates.

Table V-27 also presents pore volumes eluted from the alternative CDFs over the 10 year period. Pore volumes eluted after ten years represent less water contact than in one cycle of the sequential batch leach test. One cycle of the sequential batch leach test is equivalent to elution of 6.5 pore

Table V-27
Percolation Volumes Predicted by HELP Model

Year	Scenario					
	A		B		C	
	Per	T	Per	T	Per	T
1	6,700,094	0.263	3,622,240	0.142	4390	0.0002
2	1,031,907	0.303	1,273,638	0.192	4256	0.0003
3	487,183	0.322	740,225	0.221	4131	0.0005
4	313,652	0.334	517,104	0.241	4084	0.0007
5	228,395	0.343	393,028	0.257	4072	0.0008
6	178,930	0.350	316,174	0.269	4071	0.0010
7	146,514	0.356	263,613	0.279	4070	0.0011
8	124,008	0.361	226,068	0.288	4081	0.0013
9	106,756	0.365	196,569	0.296	4068	0.0015
10	93,771	0.369	174,016	0.303	4067	0.0016

PER: percolation into foundation soils, cu ft.

T: pore volume eluted.

volumes of Santa Fe Channel sediment at the in situ water content. Thus, during the period of maximum percolation rates (first two years after filling), leachate contaminant concentrations will generally be at the concentrations observed in the first cycle of the sequential batch leach test. As previously discussed, leachate contaminant concentrations in the first cycle are often the lowest or near the lowest leachate contaminant concentrations observed in the sequential batch leach tests. Maximum leachate concentrations will occur many years after filling is completed and when percolation rates are minimal.

Since worst-case leachate movement will require many years, leachate quality for the first cycle is appropriate for comparison to assumed regulatory limits. Table V-28 compares first cycle leachate to assumed regulatory limits issued by the California Regional Water Quality Control Board and the assumed maximum contaminant levels (MCLs) established under the Safe Drinking Water Act. The assumed MCLs were not exceeded by any of the leachate data. The assumed effluent or discharge limits for copper and zinc were exceeded. The assumed receiving water limits were exceeded for all contaminants.

Table V-28

Comparison of Leachate Concentrations ($\mu\text{g/L}$) to Assumed
Regulatory Limits for Santa Fe Channel Sediment

<u>Constituent</u>	<u>Step 1 Anaerobic Leachate</u>	<u>Step 1 Aerobic Leachate</u>	<u>Maximum Contaminant Level*</u>	<u>Effluent Limits</u>	<u>Receiving Water Limits</u>
Arsenic	26.6	22.5	50	50	1
Cadmium	0.91	0.54	10	1.8	0.65
Chromium	6.32	2.1	50	16	98
Copper	9.79	27.8		9.2	6.5
Mercury	0.05	0.082	2	2.4	0.012
Zinc	73.7	41.0		65	59
Tributyltin	0.006	0.006		0.08	0.02

* Level specified for compliance with Safe Drinking Water Act. In the absence of State Groundwater quality standards for an undetermined disposal site, Federal Safe Drinking Water Quality Criteria were assumed to give perspective to test results.

PART VI: CONCLUSIONS AND RECOMMENDATIONS

Santa Fe Channel sediment metal concentrations are in the range of those found in normal agricultural soils with the exception of nickel. Santa Fe Channel sediment contains nickel concentrations at the maximum concentration allowed for agricultural production. Sediment butyltin concentrations are low at 15 ppb, but are higher than found at a previous tested upland reference disposal site at Twitchell Island. Santa Fe channel sediment contains some PAHs at concentrations higher than Twitchell Island. Santa Fe sediment contained approximately 200 ppb DDT and DDD which has given rise to concern.

Neomysis exposed to the Santa Fe channel sediment modified elutriate demonstrated no toxicity. The Santa Fe sediment therefore appears to have very little potential for adversely affecting marine aquatic organisms.

Contaminants in surface runoff from the Santa Fe channel sediment was mostly bound to the sediment particulates. Significant quantities of arsenic, cadmium, chromium, copper, zinc, tributyltin, and 4,4-DDT could be eroded from an upland disposal site during the wet, unoxidized stage if the suspended solids were not removed from the runoff. Only arsenic exceeded any of the assumed criteria for soluble contaminants. Potential surface runoff water quality problems during the wet, unoxidized period of upland disposal would therefore be mostly associated with erosion of particulates. Management of the upland disposal site to remove particulates from surface runoff, would remove 90 to 99 percent of all contaminants in surface runoff. A very small mixing zone ratio of 3 to 1 would be required to dilute soluble arsenic to the assumed Receiving Water Quality Limitation standard.

Potential problems in surface runoff from dry, oxidized sediments are similar to those in surface runoff from the wet, unoxidized sediment. Again only soluble arsenic exceeded the assumed Receiving Water Quality Limitation standard in both sediments. Consideration of a small mixing zone and removal of the suspended solids should eliminate the need for further restrictions particularly with regard to treatment of soluble contaminants. A mixing zone of less than 10 to 1 would be required to dilute unfiltered contaminant concentrations to less than or equal to the strictest assumed criteria, and a mixing zone of about 3 to 1 would be required for soluble arsenic.

Exposure of sensitive test animals to Santa Fe sediment runoff water showed little potential for aquatic toxicity. Mean survival was usually

greater than 90 percent for all treatments. These bioassays do not, in any way, indicate aquatic toxicity associated with this runoff water.

Sequential batch and column leach tests indicated a complicated leaching process for contaminants in Santa Fe sediment. A progressive increase in contaminant concentrations was observed as the sediment was washed in sequential batch leach tests or continuously washed in column leach tests. The batch tests indicated that peak concentrations occurred after most sediment salts were washed out. Thereafter, concentrations tended to decrease. Column leach data were in general agreement with increasing concentration trends followed by decreasing concentration trends, although the duration of the column tests was not sufficient to establish decreasing trends for some contaminants.

For the type of leaching behavior observed, initial pore water quality in a confined disposal facility for Santa Fe dredged material does not represent worst-case leachate quality. Leachate quality will get progressively worse until the salt content of the sediment has been removed. The time required to reach maximum leachate contaminant concentrations may be on the order of hundreds of years, depending on climatic conditions and disposal site-specific engineering controls.

Comparisons of initial contaminant concentrations in batch leachates to assumed regulatory criteria indicated no exceedances of assumed drinking water limits. Assumed state of California effluent and receiving water limits were exceeded. When sufficient rainwater has percolated through the dredged material for peak contaminant concentrations to occur (probably hundreds of years), present assumed drinking water criteria for arsenic and chromium will probably be exceeded.

Evaluation of leachate controls using the Hydrologic Evaluation of Land-fill Performance (HELP) computer model showed that initial leachate generation is primarily due to drainage of excess water in the dredged material. Leachate generation rates can be reduced by reducing the surface area of the disposal site and by constructing a composite liner.

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APPENDIX A: SEDIMENT COLLECTION AND CHEMICAL CHARACTERIZATION

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2.0 FIELD SAMPLING

2.1 INTRODUCTION AND OBJECTIVES

The goal of the field sampling was to collect samples appropriate for determination of the horizontal and vertical distribution of chemicals in the sediments. Specific objectives were as follows:

1. To collect sediment cores from 42 sites in Richmond Harbor Channel to project depth of -38 ft MLLW plus 1 ft overdraft plus 1 ft of exposed sediment (Figure 3). Sediment from 26 of these cores were to undergo bulk sediment analysis only; the remaining 16 were to be archived for possible future analysis.
2. To collect five cores from the proposed turning basin in Richmond Harbor Channel and one core from the proposed widening area at the junction of Richmond Harbor and Santa Fe Channels (Figure 3). These areas have not been previously dredged and the cores from these areas were expected to be 20 to 35 ft long. Samples prepared from these sediment cores will undergo bulk sediment analyses only.
3. To collect sediment cores from 60 sites in Santa Fe Channel to project depth of -38 ft plus 1 ft overdraft and 1 ft exposed sediment to a total depth of -40 ft MLLW. The 60 sites, divided into 18 sites in Reach A, 18 in Reach B, and 24 in Reach C (Figure 4), were chosen by USACE's Waterways Experiment Station (WES) in Vicksburg, MS. Following a compositing scheme designed by WES, sediments from these cores were to undergo bulk sediment, interstitial water, and elutriate chemistry analyses.
4. To collect ten gallons of water from the center of Santa Fe Channel for use in elutriate sample preparation.

Field sampling operations were initiated on April 3, 1989 and completed on April 12, 1989. Of the total 108 sediments stations planned for sampling, 96 sites were actually sampled (Figures 3 and 4). Twelve sediment samples in Santa Fe Channel were not collected because the sediment surface was already below the project depth (-38 ft MLLW plus 1 ft overdraft and 1 ft exposed surface) (Figure 4). The 48 sampling sites in Richmond Harbor Channel (Figure 3) were chosen by USACE and Battelle following completion of Task 1 (Background Data Collection).

The 42 cores from Richmond Harbor Channel (Objective 1) and the 60 from Santa Fe Channel (Objective 3) will be referred to as short cores, as most

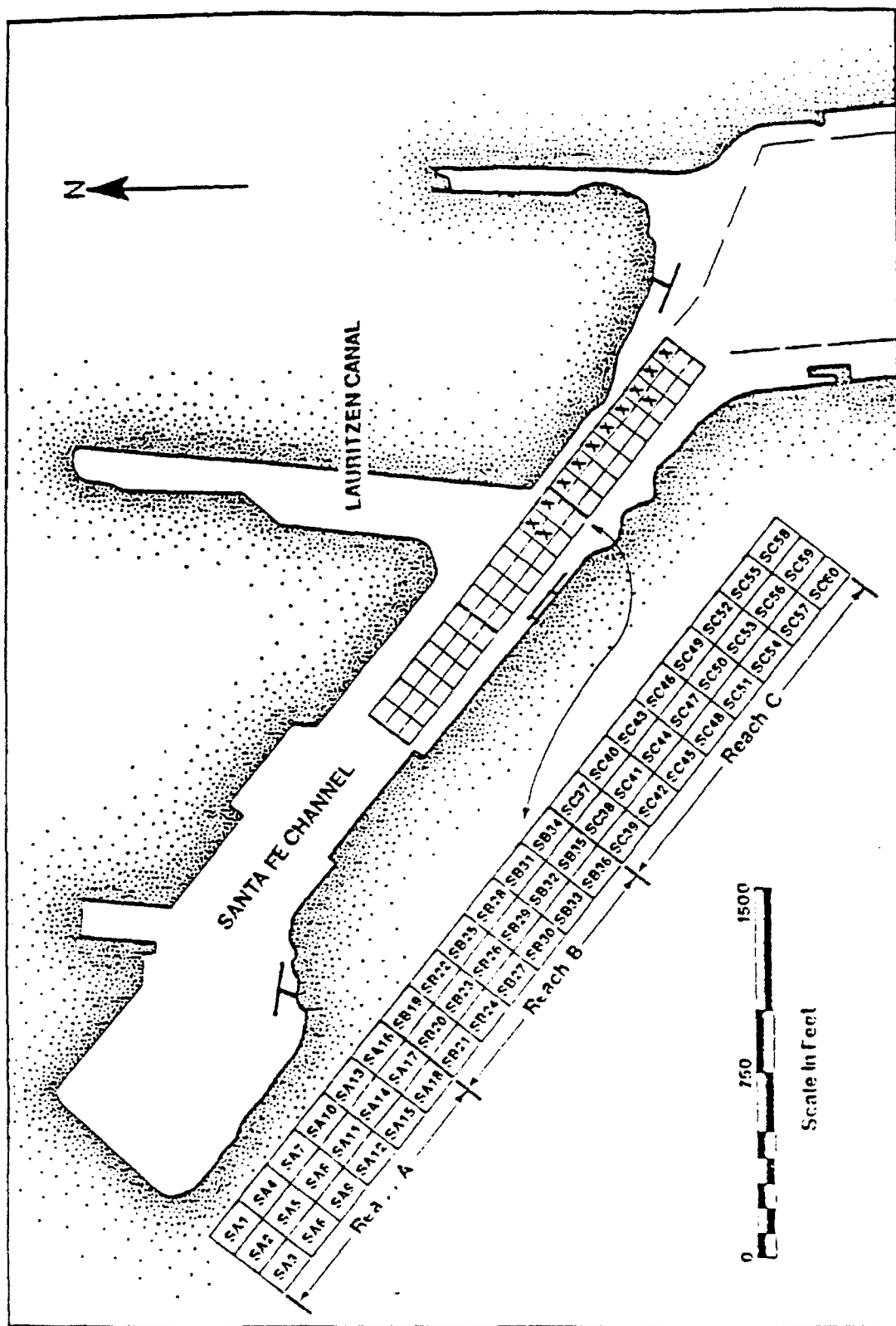


FIGURE 4. LOCATION OF SAMPLING STATIONS IN SANTA FE CHANNEL. Stations marked with X were not sampled.

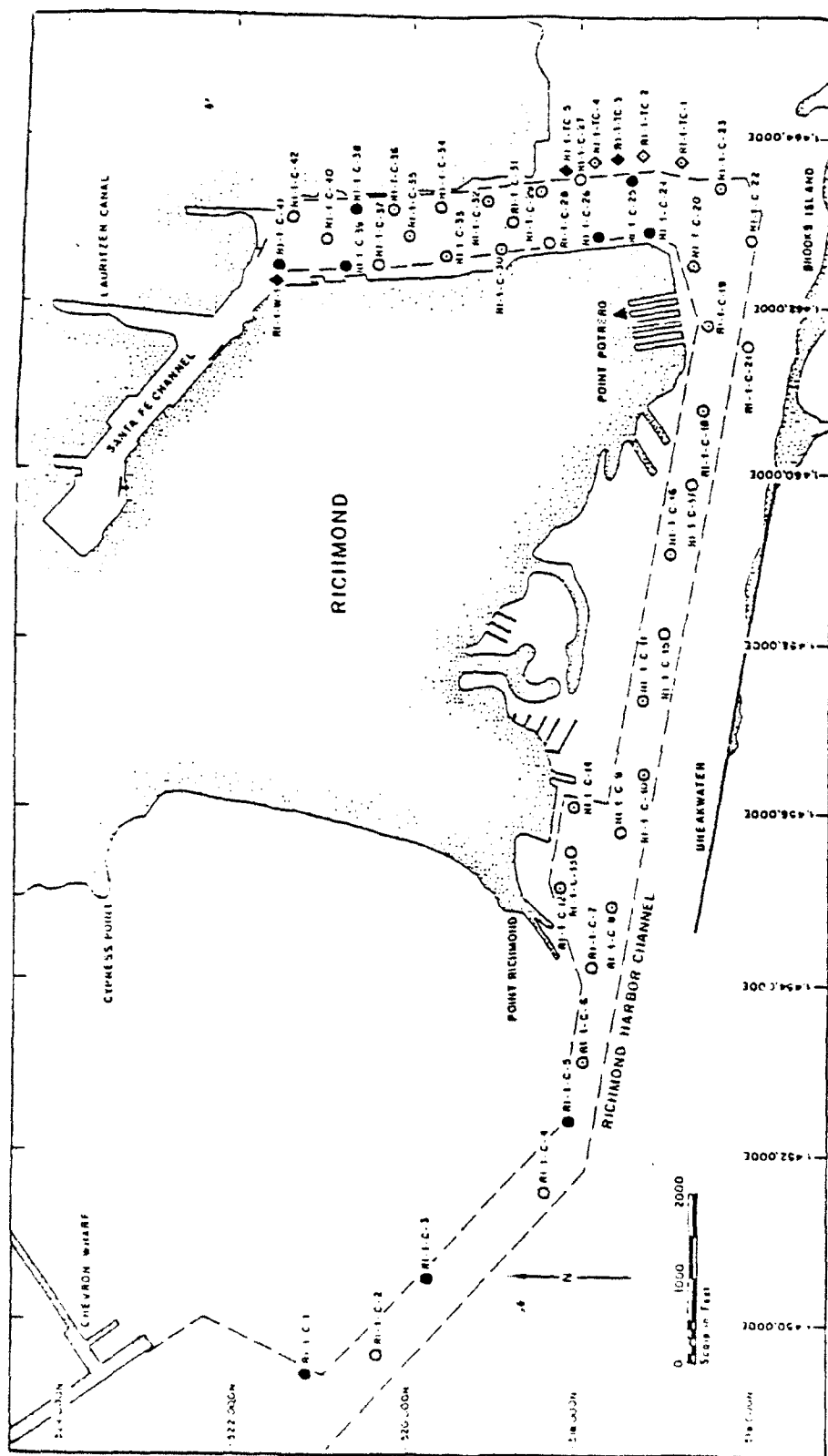


FIGURE 3. LOCATION OF SAMPLING STATIONS IN RICHMOND HARBOR CHANNEL (diamond-long cores, \diamond -analyzed for "A" group analytes, \diamond -analyzed for "B" group analytes; circle-short cores, \bullet -analyzed for "A" group analytes (see text), \circ -analyzed for "B" group analytes; Δ -staying area).

were expected to be less than 10 ft long. The six cores from the undredged areas (Objective 2) are referred to as long cores. In Richmond Harbor Channel, 13 stations were successfully sampled with the gravity corer. The six long core stations (Stations RI-1-W-1 and RI-1-TC-1 through RI-1-TC-5) were sampled with the vibratory corer as were the remaining 29 short core stations in Richmond Harbor. In Santa Fe Channel, 48 stations were successfully cored with the vibratory corer, and 12 sites were not attempted because the sediment surface was already below project depth. Approximately ten gallons of water was collected from the center of Santa Fe Channel for laboratory preparation of elutriate samples. Sample collection information is summarized in Table 1.

2.2 VESSELS AND NAVIGATION

A total of four vessels were used to complete the field sampling: two tugboats, a derrick barge, and an inflatable boat. Different vessels were required for the operation of each of the two types of core samplers: a gravity corer and vibratory corer. The core samplers are described in the Section 2.3.1. The 40-ft tugboat California Eagle, operated by Tom Decker of Slackwater Towboat Company of Richmond, California, was used for gravity coring. Vibratory coring operations took place aboard a derrick barge provided by Manson Pacific Construction and Engineering Company of Richmond. The derrick barge, DB-17, was a 112-x-52-ft platform with a 130-ft crane. The barge was maneuvered by the tugboat Bearcat, operated by skipper Joe Wirth and Bill Hammond of Westar Marine Services.

Navigation, or positioning on the sampling sites, was provided by a team of two licensed surveyors from Land and Sea Surveys of Ventura, California. The fourth vessel, a small inflatable boat, was operated by one surveyor, while the second surveyor worked from a survey control point on shore. Sampling sites were located using a Geodimeter laser/range azimuth positioning system, and marked by a retrievable buoy. The surveyors also recorded the actual water depth at the station, then applied a tidal correction for the time to obtain a corrected depth relative to MLLW. Portable radios were used to communicate information between surveyors, scientists, and vessel crews. If the corrected depth at the sampling station

TABLE 1. Sample Collection Information for Santa Fe and Richmond Harbor Channels

California State		Zone III Coordinates		Date Sampled	Start Time	Corer Type	Corrected Depth (MLW)	Required Core (FT)	Collected Core (FT)	Length		Comments
Station	East (X)	North (Y)	Upper (FT)							Lower (FT)		
Short Cores: Richmond Harbor												
RI-1-C-1	1,449,413	521,122	5 APR	10:50	GRAVITY	-34.7	5.3	6.3	4.3	2.0		
RI-1-C-2	1,449,601	520,332	5 APR	12:05	GRAVITY	-36.7	3.3	4.7	2.3	2.4		
RI-1-C-3	1,450,533	519,762	10 APR	09:06	VIBRATORY	-33.6	6.2	7.2	5.2	2.0		
RI-1-C-4	1,451,525	518,371	5 APR	11:30	GRAVITY	-36.1	3.9	5.0	2.9	2.1		
RI-1-C-5	1,452,380	518,112	5 APR	12:40	GRAVITY	-35.6	4.2	6.0	3.2	2.6		
RI-1-C-6	1,453,063	517,915	10 APR	09:44	VIBRATORY	-32.0	8.0	8.0	7.0	1.0	3 Attempts	
RI-1-C-7	1,454,126	517,824	10 APR	10:39	VIBRATORY	-30.7	9.3	8.3	8.3	----	Archive core: no lower section	
RI-1-C-8	1,454,907	517,689	5 APR	15:59	GRAVITY	-34.0	6.0	6.2	5.0	1.2		
RI-1-C-9	1,455,788	517,600	5 APR	16:16	GRAVITY	-34.2	5.8	6.5	4.8	1.7		
RI-1-C-10	1,456,433	517,248	5 APR	16:21	GRAVITY	-34.4	5.6	6.0	4.6	1.4		
RI-1-C-11	1,457,319	517,257	6 APR	08:49	GRAVITY	-34.0	6.0	7.0	5.0	2.0		
RI-1-C-12	1,455,139	516,190	5 APR	14:53	GRAVITY	-33.1	6.9	7.3	5.9	1.4		
RI-1-C-13	1,455,677	516,087	5 APR	14:39	GRAVITY	-32.7	7.3	6.4*	6.0	0.4		
RI-1-C-14	1,456,101	516,034	5 APR	15:22	GRAVITY	-33.5	6.5	6.3*	5.5	0.8	Middle sediment lost: analyze lower	
RI-1-C-15	1,456,126	517,006	6 APR	08:30	GRAVITY	-36.4	3.6	4.0	2.9	1.4		
RI-1-C-16	1,459,094	516,945	10 APR	11:12	VIBRATORY	-31.6	6.4	7.7*	7.4	0.3	2 attempts with gravity core 4/8	
RI-1-C-17	1,459,933	516,762	10 APR	12:02	VIBRATORY	-33.6	6.4	5.6*	5.4	----	2nd attempt; 2 gravity core tries 4/5	
RI-1-C-18	1,460,752	516,695	10 APR	13:00	VIBRATORY	-33.4	6.6	6.0*	5.3	0.7	2nd attempt; 1 gravity core try 4/5	
RI-1-C-19	1,461,753	516,529	5 APR	17:50	GRAVITY	-35.5	4.5	4.8	3.5	1.3	1st 2 attempts too short	
RI-1-C-20	1,462,462	516,701	10 APR	13:42	VIBRATORY	-34.7	5.3	6.1	4.3	2.8	1 gravity corer attempt 4/5	
RI-1-C-21	1,461,516	516,074	10 APR	13:22	VIBRATORY	-34.2	5.6	5.5*	4.8	0.7	1 gravity corer attempt 4/5	
RI-1-C-22	1,462,784	516,018	10 APR	14:03	VIBRATORY	-34.3	5.7	6.5	4.7	3.6	1 gravity corer attempt 4/5	
RI-1-C-23	1,463,294	516,421	10 APR	14:19	VIBRATORY	-31.2	6.6	10.7	7.6	2.9		
RI-1-C-24	1,462,866	517,209	10 APR	14:37	VIBRATORY	-34.3	5.7	7.6	4.7	2.9		
RI-1-C-25	1,463,473	517,426	9 APR	16:04	VIBRATORY	-34.0	6.0	6.0	5.0	1.0		
RI-1-C-26	1,462,787	517,807	10 APR	14:52	VIBRATORY	-33.6	6.4	6.4	5.4	1.0		

* and ** -- See text for explanation of results.

TABLE 1. (continued)

California State											
Station	Zone III Coordinates		Date Sampled	Start Time	Corer Type	Corrected Depth (MLW)	Required Core (ft)	Collected Core (ft)	Length Upper (ft)	Length Lower (ft)	Comments
	East (X)	North (Y)									
Short Cores: Richmond Harbor (continued)											
RI-1-C-27	1,483,492	518,015	9 APR	15:44	VIBRATORY	-35.0	5.0	4.8*	4.0	0.0	
RI-1-C-28	1,482,712	518,381	10 APR	15:15	VIBRATORY	-34.1	5.9	5.4*	4.9	0.5	
RI-1-C-29	1,483,334	518,493	9 APR	15:20	VIBRATORY	-34.2	5.8	6.5	4.8	1.7	
RI-1-C-30	1,482,844	518,942	10 APR	15:48	VIBRATORY	-33.8	6.3	6.2*	5.3	0.8	
RI-1-C-31	1,482,985	518,810	10 APR	15:30	VIBRATORY	-34.4	5.8	7.2	4.6	2.6	
RI-1-C-32	1,483,212	519,097	9 APR	15:50	VIBRATORY	-35.4	4.6	7.0	3.6	3.4	
RI-1-C-33	1,482,560	519,578	10 APR	16:10	VIBRATORY	-33.6	6.4	6.1	5.4	0.7	
RI-1-C-34	1,483,157	519,834	9 APR	14:40	VIBRATORY	-37.1	2.9	5.0	1.9	3.1	
RI-1-C-35	1,482,805	520,010	10 APR	16:29	VIBRATORY	-35.5	4.5	7.5	3.5	4.0	
RI-1-C-36	1,483,138	520,209	9 APR	14:25	VIBRATORY	-35.4	4.6	6.3	3.6	2.7	
RI-1-C-37	1,482,460	520,379	10 APR	16:46	VIBRATORY	-38.9	3.1	4.6	2.1	2.5	
RI-1-C-38	1,483,118	520,638	9 APR	13:54	VIBRATORY	-36.1	3.9	6.6	2.9	3.7	2nd attempt
RI-1-C-39	1,482,418	520,728	10 APR	17:00	VIBRATORY	-33.8	6.2	6.2	5.2	1.0	
RI-1-C-40	1,482,743	520,946	10 APR	17:10	VIBRATORY	-37.0	3.0	3.1	2.0	1.1	
RI-1-C-41	1,482,403	521,508	10 APR	17:32	VIBRATORY	-35.3	4.7	6.3	3.7	2.6	
RI-1-C-42	1,483,032	521,346	9 APR	13:28	VIBRATORY	-34.1	5.9	7.9	4.9	3.0	2nd attempt
Short Cores: Santa Fe Channel											
SA-1	1,460,913	522,918	7 APR	13:18	VIBRATORY	-36.0	4.0	3.0	3.0	1.0	2 gravity corer attempts 4/6
SA-2	1,480,870	522,865	7 APR	12:52	VIBRATORY	-37.3	2.7	3.0	LOST	LOST	Archived -40 to -44 ft section
SA-2 REP 2	1,480,870	522,865	7 APR	13:40	VIBRATORY	-37.3	2.7	3.0	1.7	1.0	2 gravity corer attempts 4/6
SA-3	1,460,827	522,814	9 APR	08:40	VIBRATORY	-36.7	3.3	3.0	2.3	1.0	2 gravity corer attempts 4/6
SA-4	1,460,990	522,851	7 APR	14:09	VIBRATORY	-37.1	2.9	3.0	1.9	1.0	
SA-5	1,460,946	522,800	7 APR	14:22	VIBRATORY	-37.2	2.8	2.5*	1.8	0.7	
SA-6	1,460,903	522,749	9 APR	08:54	VIBRATORY	-36.2	3.8	3.0	2.8	1.0	

* and ** -- See text for explanation of results.

TABLE 1. (continued)

California State												
Station	Zone III Coordinates		Date Sampled	Start Time	Corer Type	Corrected Depth (MLW)	Required Core (ft)	Collected Core (ft)	Length		Comments	
	East (X)	North (Y)							Upper (ft)	Lower (FT)		
Short Cores: Santa Fe Channel (continued)												
SA-7	1,461,066	522,787	7 APR	15:55	VIBRATORY	-38.5	1.5	>4.0	0.5	1.0		
SA-8	1,461,022	522,738	7 APR	15:25	VIBRATORY	-37.5	2.5	>4.0	1.5	1.0		
SA-9	1,460,979	522,684	9 APR	09:25	VIBRATORY	-35.7	4.3	>4.3	3.3	1.0		
SA-10	1,461,142	522,722	7 APR	18:25	VIBRATORY	-38.7	1.3	>2.0	0.3	1.0		
SA-11	1,461,099	522,671	7 APR	18:13	VIBRATORY	-37.9	2.1	>4.0	1.1	1.0		
SA-12	1,461,055	522,620	9 APR	09:43	VIBRATORY	-35.7	4.3	>4.3	3.3	1.0		
SA-13	1,461,218	522,667	7 APR	17:15	VIBRATORY	-36.1	3.9	>4.0	2.9	1.0		
SA-14	1,461,175	522,606	7 APR	16:45	VIBRATORY	-36.1	3.9	>4.0	2.9	1.0		
SA-15	1,461,132	522,555	9 APR	09:51	VIBRATORY	-36.8	3.2	>3.2	2.2	1.0		
SA-16	1,461,295	522,592	7 APR	17:51	VIBRATORY	-37.5	2.5	>10.0	1.5	1.0		
SA-17	1,461,261	522,541	7 APR	17:20	VIBRATORY	-37.5	2.5	>4.0	1.5	1.0		
SA-18	1,461,208	522,490	9 APR	10:12	VIBRATORY	-35.0	6.0	>5.0	4.0	1.0		
SB-19	1,461,370	522,528	8 APR	09:12	VIBRATORY	-38.1	1.9	>4.0	0.9	1.0	2 gravity corer attempts 4/8	
SB-20	1,461,327	522,477	8 APR	09:27	VIBRATORY	-37.1	2.9	>4.0	1.9	1.0	2nd attempt	
SB-21	1,461,284	522,426	9 APR	10:28	VIBRATORY	-36.0	4.0	>4.0	3.0	1.0		
SB-22	1,461,447	522,463	8 APR	10:00	VIBRATORY	-33.9	6.1	>6.0	5.1	1.0		
SB-23	1,461,404	522,412	8 APR	09:43	VIBRATORY	-37.5	2.5	>3.0	1.5	1.0		
SB-24	1,461,360	522,361	9 APR	10:42	VIBRATORY	-36.4	3.6	>3.6	2.6	1.0		
SB-25	1,461,523	522,398	8 APR	10:30	VIBRATORY	-36.7	3.3	>3.3	2.3	1.0		
SB-26	1,461,480	522,347	8 APR	10:16	VIBRATORY	-37.0	3.0	>3.0	2.0	1.0		
SB-27	1,461,436	522,296	9 APR	10:57	VIBRATORY	-35.9	4.1	>4.1	3.1	1.0		
SB-28	1,461,816	522,348	8 APR	10:54	VIBRATORY	-39.1	0.9	>5.0	---	1.0	Kept 1 ft for lower only	
SB-29	1,461,556	522,282	8 APR	10:45	VIBRATORY	-37.6	2.4	>5.0	1.4	1.0		
SB-30	1,461,513	522,231	9 APR	11:58	VIBRATORY	-38.8	3.4	>4.0	2.4	1.0		
SB-31	1,461,693	522,284	8 APR	-----	-----	>40	---	---	---	---	Below project depth	

TABLE 1. (continued)

California State											
Station	Zone III Coordinates		Date Sampled	Start Time	Corer Type	Corrected Depth (MLW)	Required Core (ft)	Collected Core (ft)	Length		Comments
	East (X)	North (Y)							Upper (ft)	Lower (ft)	
Short Cores - Santa Fe Channel (continued)											
SR 32	1,461,649	622,231	8 APR	-----	-----	>-40	---	----	---	---	Below project depth
SR 33	1,461,689	622,187	9 APR	11:44	VIBRATORY	-36.4	3.6	>4.0	2.6	1.0	Below project depth
SR 34	1,461,770	622,220	8 APR	-----	-----	>-40	---	----	---	---	Below project depth
SR 35	1,461,701	622,134	8 APR	12:55	VIBRATORY	-36.9	3.1	>3.1	2.1	1.0	Below project depth
SR 36	1,461,665	622,102	8 APR	14:40	VIBRATORY	-37.1	2.9	>2.9	1.9	1.0	Below project depth
SC 37	1,461,847	622,156	8 APR	-----	-----	>-40	---	----	---	---	Below project depth
SC 38	1,461,785	622,088	8 APR	13:15	VIBRATORY	-38.2	1.6	>1.6	0.8	1.0	Below project depth
SC 39	1,461,741	622,037	8 APR	14:47	VIBRATORY	-38.1	1.9	>1.9	0.9	1.0	Below project depth
SC 40	1,461,924	622,092	8 APR	-----	-----	>-40	---	----	---	---	Below project depth
SC 41	1,461,861	622,024	8 APR	13:34	VIBRATORY	-38.3	1.7	>1.7	0.7	1.0	Below project depth
SC 42	1,461,818	621,973	8 APR	15:09	VIBRATORY	-38.9	3.1	>4.0	2.1	1.0	Below project depth
SC 43	1,462,001	622,028	8 APR	-----	-----	>-40	---	----	---	---	Below project depth
SC 44	1,461,937	621,959	8 APR	14:02	VIBRATORY	-38.8	1.2	>4.0	0.2	1.0	Below project depth
SC 45	1,461,874	621,908	8 APR	15:26	VIBRATORY	-37.4	2.6	>4.0	1.6	1.0	Below project depth
SC 46	1,462,078	621,964	8 APR	-----	-----	>-40	---	----	---	---	Below project depth
SC 47	1,462,013	621,894	8 APR	15:55	VIBRATORY	-38.4	1.6	>4.0	0.6	1.0	Below project depth
SC 48	1,461,970	621,843	8 APR	16:40	VIBRATORY	-36.3	3.7	>4.0	2.7	1.0	Below project depth
SC 49	1,462,154	621,900	8 APR	-----	-----	>-40	---	----	---	---	Below project depth
SC 50	1,462,900	621,829	8 APR	16:25	VIBRATORY	-36.5	1.5	>4.0	0.5	1.0	Below project depth
SC 51	1,462,046	621,778	8 APR	16:16	VIBRATORY	-36.3	3.7	>3.7	2.7	1.0	Below project depth
SC 52	1,462,231	621,836	8 APR	-----	-----	>-40	---	----	---	---	Below project depth
SC 53	1,462,187	621,783	8 APR	-----	-----	>-40	---	----	---	---	Below project depth
SC 54	1,462,123	621,714	8 APR	16:42	VIBRATORY	-36.3	3.7	>4.0	2.7	1.0	Below project depth
SC 55	1,462,308	621,772	8 APR	-----	-----	>-40	---	----	---	---	Below project depth

TABLE 1. (continued)

California State												
Zone III Coordinates		Date Sampled	Start Time	Corer Type	Corrected Depth (MLW)	Required Core (ft)	Collected Core (ft)	Length		Comments		
Station	East (X)							North (Y)	Upper (ft)		Lower (ft)	
Short Cores: Santa Fe Channel (continued)												
SC-66	1,462,242	621,700	6 APR	16:17	VIBRATORY	-37.9	2.1	24.0	1.1	1.0	Below project depth 2 gravity corer attempts 4/6 2 gravity corer attempts 4/6	
SC-67	1,462,199	621,649	6 APR	17:08	VIBRATORY	-35.8	4.2	24.2	3.2	1.0		
SC-68	1,462,385	621,708	6 APR	-----	-----	>40	---	---	---	---		
SC-69	1,462,318	621,635	6 APR	17:48	VIBRATORY	-37.2	2.6	22.8	1.8	1.0		
SC-80	1,462,276	621,684	6 APR	17:34	VIBRATORY	-35.7	4.3	24.3	3.3	1.0		
Long Cores: Richmond Harbor Channel												
RI-1-W-1	1,462,161	621,548	9 APR	16:46	VIBRATORY	-17.0	23.0	22	-----	-----	Corer penetrated to 25 ft, but was plugged with clay and gravel. Sediment was not kept.	
RI-1-W-1A	1,462,204	621,557	9 APR	17:55	VIBRATORY	-26.2	13.6	11.5	-----	-----	Corer penetrated 13 ft, again plugged with clay, gravel. All material saved as sample.	
RI-1-TC-1	1,463,873	616,866	10 APR	16:10	VIBRATORY	-10.7	29.3	25**	----- (a)	-----	Too short, not kept.	
RI-1-TC-1	1,463,873	616,865	11 APR	08:26	VIBRATORY	-5.2	34.0	23**	N/A	N/A	Corer penetrated 39 ft of mud. Recovered core kept (6 sections)	
RI-1-TC-2	1,463,772	617,295	11 APR	09:16	VIBRATORY	-5.2	34.0	25**	N/A	N/A	Corer penetrated 41 ft of mud. Recovered core kept (6 sections)	
RI-1-TC-3A	1,463,731	617,608	11 APR	10:15	VIBRATORY	-6.9	33.1	22**	N/A	N/A	Corer penetrated 40 ft of mud. Recovered core kept (5 sections)	

* and ** -- See text for explanation of results.

TABLE 1. (continued)

California State		Zone III Coordinates		Date Sampled	Start Time	Corer Type	Corrected Depth (MLW)	Required Core (ft)	Collected Core (ft)	Length		Comments
Station	East (X)	North (Y)	Upper (ft)							Lower (ft)		
<u>Long Cores: Richmond Harbor Channel (continued)</u>												
RI-1-1C-4	1,463,680	517,051	11 APR	10:53	VIBRATORY	-6.2	33.8	24**	N/A	N/A	Corer penetrated 38 ft of mud. Recovered core kept (8 sections)	
RI-1-1C-5	1,463,581	518,187	11 APR	13:05	VIBRATORY	-20.1	19.9	17.0**	N/A	N/A	Corer penetrated 25 ft of mud. Recovered core kept (4 sections)	
<u>Water sample: Santa Fe Channel</u>												
SB 35	1,461,701	522,134	8 APR	12:20	THREE WATER SAMPLES COLLECTED - SFC #1, #2, #3							

* and ** -- See text for explanation of results.

(a) Cores were not divided into upper and lower sections in the field. Sections for chemical analysis will be determined in laboratory.

was too deep to collect sufficient sediment for analysis and/or archiving, the station was relocated as closely as possible to the original location. The surveyor in the small boat would circle the station while watching the fathometer until an appropriate depth was found. The buoy would then be reset and the revised coordinates and new depth recorded. In Richmond Harbor Channel, revised locations were generally closer to the edge of the channel. In Santa Fe Channel, if a station could not be relocated within a 25-ft radius of the original station, the entire grid square was assumed to be too deep and, therefore, was not sampled.

2.3 SAMPLING EQUIPMENT AND PROCEDURES

2.3.1 Sediment Samples

2.3.1.1 Introduction

Sediment core samples from Richmond Harbor and Santa Fe Channels were collected with one of two types of coring devices. Because most core lengths were not expected to exceed ten feet (short cores), it was planned that sampling at most sites would be attempted with a gravity corer. At sites in previously undredged areas (long cores) and where the gravity corer was unsuccessful, a vibratory hammer corer was to be used. Both the gravity corer and vibratory corer accommodate a 3.625-in inner diameter core liner of polycarbonate Lexan. All core liners were steam-cleaned prior to use. The procedures for collecting cores with these two types of corers are detailed in the following sections.

2.3.1.2 Gravity Coring

The gravity coring device was designed to drop through the water column and penetrate sediments under its own weight and momentum. The device consisted of a 10-ft core barrel with a 4-in inner diameter, capable of collecting an 8-ft core (Figure 5). The lower end of the barrel was threaded to accommodate a cutter head designed to collect a relatively undisturbed sample. Three fins were welded to the top end of the core barrel to prevent deflection as it dropped. A bolt through the core barrel held the top of the core liner in place, and a bail welded over the top of the barrel connected it to the haul cable.

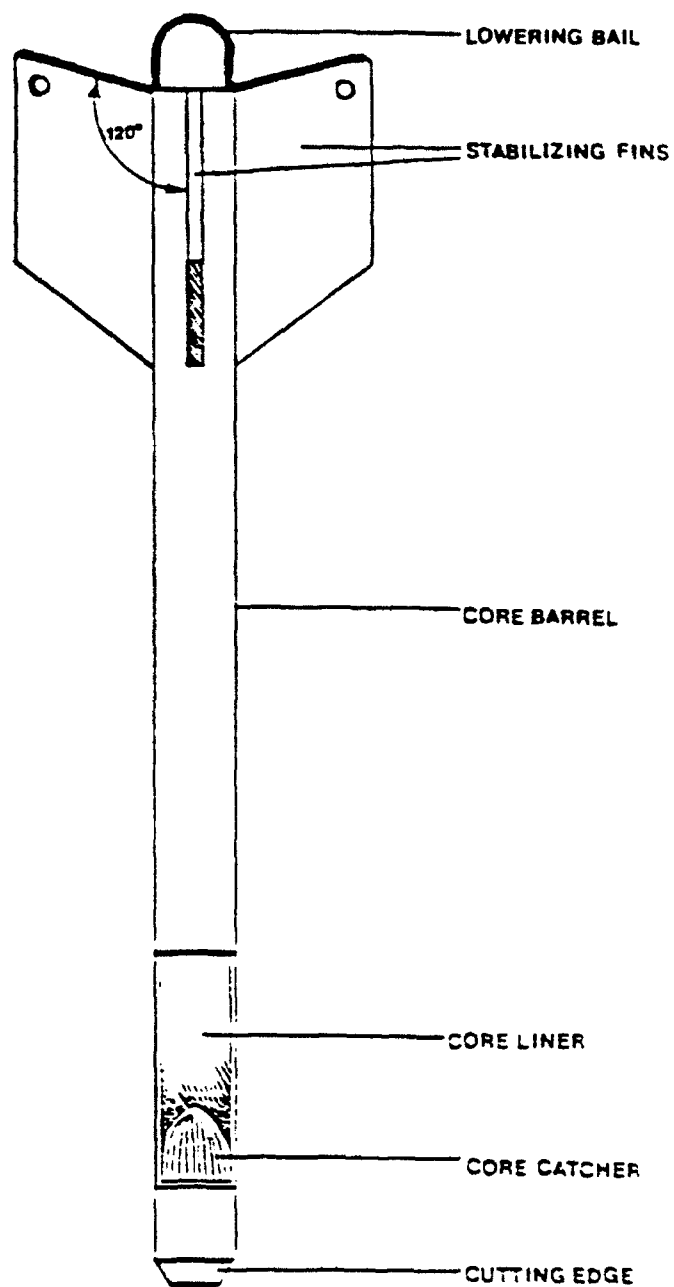


FIGURE 5. GRAVITY CORER USED TO COLLECT RICHMOND HARBOR SEDIMENT.

To collect a gravity core, a 10-ft section of Lexan core liner was loaded into the core barrel. One or more core retainers were inserted into the lower end of the core liner, after which the cutter head was screwed on to secure the core liner in the barrel. The gravity corer was deployed from a 20-ft jib mounted on the stern of the tugboat California Eagle. When the vessel was on site, the corer was lowered to the water surface and allowed to free fall through the water column and penetrate the sediment. A winch powered by compressed air was used to retrieve the corer onto the deck. The full core liner was removed from the barrel and measured from the mudline to the bottom of the core. If the attempt was successful (i.e., the full required core depth was collected), the core was capped, labeled, cut into sections, and stored as described in Section 2.3.1.4. If the attempt was unsuccessful and the required length was not collected, additional attempts were made. If these also proved unsuccessful, the site was revisited with the vibratory corer.

2.3.1.3 Vibratory Hammer Coring

The vibratory coring apparatus, operated by Manson Pacific, consists of a 50-ft long, 4-in inner diameter core barrel. Depending on the length of core required, the barrel can be loaded with 10-, 20-, 30-, or 40-ft sections of Lexan core liner. The core retainer and cutter head assemblage is the same as that used on the gravity corer. The outside of the barrel is marked at 1-ft intervals to measure the depth of penetration as the corer descends. The top end of the vibracore barrel connects to a 6-ton electric vibrating hammer suspended from the 150-ft boom of the crane aboard the derrick barge DB-17.

To collect a vibracore sample, the barge was first maneuvered into position by the tugboat Bearcat and then two stern anchors and one bow anchor were set. To save time in anchoring, the barge was usually positioned where several sites could be sampled without reanchoring. The crane was used to lift the vibratory hammer and core barrel off the barge deck and to suspend them over the water. The hammer was then coupled to the barrel and the apparatus slowly lowered through the water at the sampling site. If the weight of the vibratory hammer alone was not enough to push the core barrel

to sufficient depth, the hammer was switched on to vibrate the corer down through the sediment until the necessary depth was achieved. The crane then raised the core barrel out of the water and lowered it onto the deck. The sediment-filled core liner was pulled from the barrel and measured. Additional attempts were made at the site if an insufficient amount of sediment was collected on the first try. If the core sample was long enough, the core was capped, labeled, cut into sections, and stored in a freezer at 4°C on board the sampling vessel.

2.3.1.4 Core Sample Handling

Once a core was collected, it was measured to see if sufficient sediment was recovered. Successful core samples were then capped, labeled, and cut into sections. Short cores from Richmond Harbor Channel were cut into upper (shallower than -39 ft MLLW) and lower (deeper than -39 ft MLLW) sections. The upper section represents the material to be dredged from the channel, while the lower section represents material that would be exposed as a result of dredging. Cores of the material to be exposed (deeper than -39 ft MLLW) from each reach (A, B, and C) of Santa Fe Channel were cut to one-foot in length (-39 to -40 ft MLLW). The lower sections of all short cores and the upper sections of 16 of the short cores from Richmond Harbor Channel were to be archived intact for possible future analyses. These sections were flagged with fluorescent tape as well as labeled for ease in sample tracking. Any sections that exceeded five feet in length were cut into two shorter pieces to facilitate handling and storage. Long cores from the proposed widening and turning areas (Station RI-1-W and RI-1-TC stations) were also cut into 5-ft sections. The sealed core sections were stored in a freezer at 4°C aboard the sampling vessel until the end of the day, when they were transferred to a refrigerated truck. Sediment sample chain-of-custody records were kept up-to-date daily as cores were loaded onto the truck.

2.3.2 Water Sampling

A vacuum pump was used to collect water samples from Santa Fe Channel. Water from 18 in below the surface was pumped through acid-cleaned, solvent-rinsed Teflon tubing into clean, labeled 5-gal glass carboys. Each carboy

was sealed with a clean neoprene stopper lined with clean sheet Teflon, then stored at 4°C aboard the sampling vessel. At the end of the day, the water samples were transferred to a refrigerated truck, where they were held at 4°C until delivery to Battelle MSL in Sequim, Washington. A water sample chain-of-custody record was initiated when samples were loaded onto the truck.

2.4 FIELD SAMPLING RESULTS

2.4.1 Short Cores: Richmond Harbor Channel and Santa Fe Channel

The initial field sampling strategy called for attempting all the short core stations (Stations RI-1-C-1 through RI-1-C-42 and Stations SA-1 through SC-60) (Figures 2,3,4) with the small tug and gravity corer, then returning to any unsuccessful sites with the barge and vibracorer. After spending April 5 and 6 gravity coring aboard the California Eagle, it was evident that the barge and vibracorer combination would be more effective and efficient. In those two days, over 40 sampling attempts were made at 31 stations in both Richmond Harbor and Santa Fe Channels. When a particularly stiff layer of sediment was encountered, the weight of the gravity corer was not sufficient to penetrate the sediment to the required depth. If a successful sample (i.e., sufficiently long) could not be collected after 2 or 3 attempts, the site was revisited with the barge and vibracorer. At nine stations in Richmond Harbor Channel and one station in Santa Fe Channel (single asterisks in Table 1), the core collected was shorter than -40 ft MLLW but longer than -39 ft MLLW. These cores were not resampled because the USACE representative on board pointed out that the bottom sections were going to be archived and it was not worth the extra effort to resample for the few missing inches of core. Thirteen Richmond Harbor Channel stations were successfully sampled with the gravity corer (Table 1). The remaining 29 short cores in Richmond Harbor Channel and all of the cores in Santa Fe Channel were collected by vibratory coring as described in Section 2.3.1.3.

Vibratory coring commenced on April 7 in Santa Fe Channel. Successful short cores were obtained from 12 sites on the first day, and 25 sites on the second day. Of the 60 stations in Santa Fe Channel, 12 were already below project depth (below -40 ft MLLW): SB-31, SB-32, SC-37, SB-34, SC-40, SC-43, SC-46, SC-49, SC-52, SC-53, SC-55, SC-58 (Figure 4). One site, SB-28, was so

deep that only the lower section (between -39 and -40 ft MLLW) could be sampled. Most of these sites are on the northwest edge of the channel between the mouth of Lauritzen Canal and the junction with Richmond Harbor Channel. The remaining Santa Fe Channel sites were sampled early on the third day (April 9), then the barge moved into Richmond Inner Harbor Channel and successfully cored at eight stations. Short cores from all 21 remaining Richmond Harbor Channel stations were collected with the vibratory corer on April 10.

2.4.2 Long Cores (Undredged Areas)

The USACE plan for improvements in Richmond Harbor calls for widening the entrance to Santa Fe Channel and for a large turning basin east of Point Potrero. To characterize the sediments from these previously undredged areas, it was necessary to collect undisturbed cores that were 20 to 35 ft in length. One core from Station RI-1-W-1 was intended to represent the material to be removed from widening the entrance to Santa Fe Channel. This site was visited on April 9. The first attempt (Station RI-1-W-1) resulted in sufficient penetration of sediment (25 ft), but the sediment was not retained in the core liner. The site was relocated to slightly deeper water (Station RI-1-W-1A) and a second attempt made. On this attempt, the cutter head and bottom of the core liner were plugged with approximately two feet of gravel and pebbles embedded in very stiff clay. Even though the core barrel had penetrated the sediment to -40 ft MLLW, the gravel and clay encountered near the surface prevented any more material from entering the barrel as it pushed down through the sediment. The material collected from Station RI-1-W-1A, though it was not an undisturbed core, was capped and sealed in a short section of Lexan (approximately two feet long) and saved for analysis.

Five sampling sites were located in the proposed turning basin east of Point Potrero (Figures 2 and 3). Corrected mudline depths at these stations (RI-1-TC-1 through RI-1-TC-5) ranged from -5.2 to -20.1 ft MLLW, requiring cores 20 to 35 ft in length. Vibracoring at these stations was completed on April 11, although one unsuccessful attempt at Station RI-1-TC-1 was made on April 10. Because water was too shallow for sampling, Station RI-1-TC-3 had to be relocated 163 ft west of the planned site and was then called Station



RI-1-TC-3A. At all five stations, markings on the core barrel indicated penetration of sediment to -40 ft MLLW. However, in all cases, the amount of sediment retrieved in the core was less than the required core length (double asterisks in Table 1). Geologists often credit this loss to compaction of the sediment as the core barrel pushes through deeper sediment. Alternatively, compacted sediments in the core may have prevented some material from entering the core if that new material was less compact than the material already in the core. Apparent core loss is discussed in more detail in Section 3.6.2.

To minimize vibration as the long cores were taken, the core barrel was allowed to drop through the sediment as far as possible before the vibratory hammer was turned on. Because the entire length of the long cores was to be examined by a geologist in the laboratory, the cores were cut into 5-ft pieces rather than divided into upper and lower sections. The results of the geological analysis of the turning basin cores is presented in Section 3.6.

2.4.3 Water Samples

On April 8, approximately 10 gal of subsurface water was collected near the center of Santa Fe Channel, 40-ft northeast of station SB-35. Three carboys were each filled about two-thirds full to obtain a total of at least 10 gal of water.

APPENDIX A
Sediment Chemical Characterization

KEY

	<u>Battelle Code</u>	<u>Sponsor Code</u>
Santa Fe Channel Sediment -	232-6	RH-SR-BAT
	232-7	RH-LAB-BAT
	232-8	RH-EL-BAT
	232-9	RH-LE-BAT

SEDIMENT DATA (CF#232)
 Project: PINOLE SHOAL, WEST RICHMOND, RICHMOND
 Sponsor: SIOGEBROE

8/24/91

SEDIMENT METAL DATA

(Concentrations in mg/kg Dry Weight)

Battelle Code	Sponsor Code	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Sa	Zn
232-1	WR-PL-BAT	0.106	11.0	0.26	204	28.5	0.184	79	14.0	0.15	78
232-2	WR-LAB-BAT	0.112	8.5	0.29	212	30.5	0.183	81	15.3	0.14	81
232-3	WR-EL-BAT	0.098	10.7	0.26	187	31.9	0.186	81	14.7	0.14	83
232-4	WR-AC-BAT	0.186	8.4	0.28	179	24.0	0.128	76	13.9	0.15	75
232-5	WR-LE-BAT	0.088	9.4	0.24	248	27.1	0.157	75	14.5	0.14	76
232-6	RH-SR-BAT	0.247	7.8	0.73	188	52.7	0.269	80	27.3	0.21	111
232-7	RH-LAB-BAT	0.257	9.0	0.70	183	50.6	0.29	79	29.8	0.14	116
232-8	RH-EL-BAT	0.258	7.5	0.70	192	65.8	0.315	78	30.1	0.21	117
232-9	RH-LE-BAT	0.271	9.5	0.66	182	58.4	0.298	86	29.2	0.14	124
232-10	PS-C4-ACBAT	0.088	15.1	0.29	251	47.2	0.148	91	14.2	0.28	95
232-11	PS-C4-LABBAT	0.072	14.8	0.25	208	50.6	0.272	87	14.7	0.21	85
232-12	PS-C4-LEBAT	0.114	16.6	0.26	211	53.7	0.379	93	15.0	0.14	96
232-13	PS-C4-PLBAT	0.106	12.3	0.29	223	49.9	0.234	100	37.1	0.14	96
232-14	PS-C4-ELBAT	0.078	10.0	0.27	158	45.6	0.157	102	13.4	0.14	91

STANDARD REFERENCE MATERIAL

MESS-1 (10/16)	NC	10.1	NA	78	25.3	0.184	30.2	32.4	0.28	180.3
CERTIFIED VALUE:		(+/-1.2)	(+/- 0.1)	(+/- 11)	(+/- 3.8)	(± 0.04)	(+/- 2.7)	(+/- 6.1)	(+/- .06)	(+/- 17)
		10.6	0.59	71	25.1	0.171	29.5	34	0.34	191

U Indicates that analyte was not detected above detection limit shown.

NC Indicates not certified

2323sed

SEDIMENT DATA
Project: PINE COAL, WEST RICHMOND, RICHMOND
Sponsor: SKOCERBOE

2/6/91

SEDIMENT BUTYLIN RESULTS

Sample Code	Sponsor Code	(Concentrations in ug/kg Dry Weight)					% Surrogate Recovery PROPYLIN (1)
		TETRA-BUTYLIN	TRI-BUTYLIN	DI-BUTYLIN	MONO-BUTYLIN		
232-1	WR-PL-BAT	0.7 U	1.0	0.7 U	0.6 U	37%	37%
232-2	WR-LAB-BAT	0.5 U	1.0	0.7 U	0.5 U	37%	37%
232-3	WR-EL-BAT	0.8 U	1.3	0.7 U	0.7 U	33%	33%
232-4	WR-AC-BAT	0.9 U	1.3	0.8 U	0.8 U	42%	42%
232-5	WR-LE-BAT	0.6 U	1.1	0.6 U	0.6 U	35%	35%
232-6	RH-SR-BAT	0.6 U	5.7	5.0	1.7	36%	36%
232-7	RH-LAB-BAT	0.8 U	5.6	6.6	1.7	30%	30%
232-8	RH-EL-BAT	0.6 U	7.3	6.6	2.6	35%	35%
232-9	RH-LE-BAT	0.8 U	6.8	5.7	2.0	35%	35%
232-10	PS-C4-ACBAT	0.7 U	1.1	0.7 U	0.7 U	31%	31%
232-11	PS-C4-LABBAT	0.6 U	1.1	0.6 U	0.5 U	16%	16%
232-12	PS-C4-LEBAT	0.7 U	1.2	0.7 U	0.7 U	26%	26%
232-12 REP	PS-C4-LEBAT REP	0.8 U	1.5	0.7 U	0.7 U	37%	37%
232-13	PS-C4-PLBAT	0.6 U	1.0	0.6	0.5 U	26%	26%
232-14	PS-C4-ELBAT	0.8 U	1.1	0.7 U	0.7 U	29%	29%
	METHOD BLANK	0.7 U	1.1	0.6 U	0.7 U	29%	29%

MATRIX SPIKE RECOVERIES: (232-12 sample spiked)
(Spiked with 156 ppb) NS 48% 35% 21% 19%

STANDARD REFERENCE MATERIAL:

PACS-1

CERTIFIED VALUES:

(1) Due to consistently low recoveries of the propyltin surrogate, it was discovered that this compound does not accurately reflect tributyltin recovery. U indicates that the analyte was not detected above the detection limits shown.

NS indicates not spiked

2325ed

SEDIMENT DATA

Project: PINOLE SHOAL, WEST RICHMOND, RICHMOND
Sponsor: SIOGEBROE

2/7/91

SEDIMENT PAH DATA

(Concentrations in ug/kg Dry Weight)

	Sponsor Code : 232-1	232-2	232-3	232-4	232-5	232-6	232-7	232-8	232-9	232-10
	Bottle Code: WR-PL-BAT	WR-LAB-BAT	WR-EL-BAT	WR-AC-BAT	WR-LE-BAT	RH-SR-BAT	RH-LAB-BAT	RH-EL-BAT	RH-LE-BAT	PS-C4-ACBAT
NAPHTHALENE	32.8 U	24.6 U	29.0 U	26.2 U	22.3 U	20.1 U	23.8 U	24.3 U	23.4 U	27.4 U
ACENAPHTHYLENE	4.9 U	10.1	28.0	9.7	16.2	3.1 U	4.3	3.9	5.2	4.2 U
ACENAPHTHENE	12.4 U	13.5	22.9	9.9 U	11.8	7.6 U	9.0 U	9.2 U	8.9 U	10.4 U
FLUORENE	8.9 U	14.4	30.7	9.8	13.9	6.1 U	7.8	9.7	16.0	6.3 U
PHENANTHRENE	133.0	263.0	803.0	184.0	285.0	39.2	57.6	69.3	82.8	12.9
ANTHRACENE	22.9	67.1	109.0	31.4	58.6	12.6	23.0	34.5	84.0	4.9 U
FLUORANTHENE	248.0	328.0	730.0	260.0	475.0	66.6	93.5	99.8	160.6	8.8
PYRENE	318.0	425.0	882.0	338.0	606.0	109.0	159.1	189.3	329.7	14.8
BENZANTHRACENE	152.0	239.0	447.0	154.0	307.0	76.4	144.6	120.8	237.6	14.1
CHRYSENE	112.0	161.0	280.0	92.5	206.0	64.0	101.1	152.8	317.6	4.9
BENZO(B,K)FLUORANTHENE*	469.0	503.0	791.0	343.0	806.0	328.0	625.1	603.0	1054.2	13.2
BENZO(A)PYRENE	332.0	357.0	670.0	301.0	671.0	168.0	292.4	293.1	491.0	6.3
INDENO(1,2,3-cd)PYRENE	201.0	244.0	421.0	210.0	507.0	93.3	148.7	164.6	305.4	6.6 U
DBENZO(A,H)ANTHRACENE	4.5 U	41.1	88.2	30.1	80.7	24.1	34.7	35.1	71.7	3.8 U
BENZO(G,H)PERYLENE	324.0	399.0	663.0	353.0	754.0	147.4	221.3	203.8	346.0	10.9
SURROGATE RECOVERY:										
D10-FLUORENE	88%	86%	77%	74%	76%	62%	100%	95%	89%	41%
D10-ANTHRACENE	92%	70%	71%	93%	94%	63%	104%	100%	96%	80%
D10-PYRENE	76%	74%	81%	79%	75%	55%	83%	97%	95%	49%

U indicates analyte not detected at or above detection limit shown

* All benzo(a)fluoranthene isomers are quantified together

232sed

SEDIMENT DATA

Project: PINOLE SHOAL, WEST RICHMOND, RICHMOND
 Sponsor: SKOGERBOE

(CF#232)

2/7/91

SEDIMENT PAH DATA

(Concentrations in ug/kg Dry Weight)

Sponsor Code : 232-11 232-12 232-13 232-14
 Battelle Code: PS-C4-LABBAT PS-C4-LEBAT PS-C4-PLBAT PS-C4-ELBAT METHOD:BLANK

NAPHTHALENE	20.3 U	24.5 U	21.6 U	23.5 U	1.5 U
ACENAPHTHYLENE	3.1 U	3.7 U	3.3 U	3.6 U	0.22 U
ACENAPHTHENE	7.7 U	9.3 U	8.2 U	8.9 U	0.56 U
FLUORENE	6.2 U	7.5 U	6.6 U	7.1 U	0.44 U
PHENANTHRENE	8.2 U	14.6	22.3	12.7	0.59 U
ANTHRACENE	3.6 U	4.4 U	3.8 U	4.2 U	0.26 U
FLUORANTHENE	7.1	10.8	21.3	6.0 U	0.37 U
PYRENE	9.3	14.2	24.9	5.8	0.28 U
BENZANTHRACENE	8.4	16.8	25.8	5.5	0.26 U
CHRYSENE	3.7	6.0	10.8	3.6 U	0.22 U
BENZO(b)FLUORANTHENE *	9.8	14.7	21.6	5.8	0.28 U
BENZO(a)PYRENE	3.9	5.1	12.5	3.6 U	0.22 U
INDENO(1,2,3-cd)PYRENE	4.9 U	5.9 U	6.8	5.7 U	0.35 U
DIBENZO(a,h)ANTHRACENE	2.8 U	3.4 U	3.1 U	3.3 U	0.2 U
BENZO(g,h)PERYLENE	6.5	6.2	23.4	2.9 U	0.18 U
SURROGATE RECOVERY:					
D10-FLUORENE	64%	57%	87%	75%	93%
D10-ANTHRACENE	78%	66%	89%	90%	97%
D10-PYRENE	66%	64%	79%	80%	88%

U indicates analyte not detected at or above detection limit shown
 * All benzofluoranthene isomers are quantified together

SEDIMENT DATA
Project: **P**
Sponsor: **S**

SEDIMENT DATA (CF #232)
Project: PINOLE SHOW, WEST RICHMOND, RICHMOND
Sponsor: SNOODGEBOX

7/31/91

SEDIMENT PESTICIDE DATA

(Concentrations in upper Dry Weir)

Bulletin Code: 232-6
Sponsor Code: 004-554-

232-7	232-8	232-9
SHALAB-BAY	PALE-BAY	PALE-BAY
		METHOD BLAK

ALDRIN	ALDRIN
B-BHC	B-BHC
B-BHC	B-BHC
D-BHC	D-BHC
CHLORDANE	CHLORDANE
4,5DD	4,5DD
4,5DDE	4,5DDE
4,5DDT	4,5DDT
DELDRIN	DELDRIN
DIOSULFAN I	DIOSULFAN I
DIOSULFAN II	DIOSULFAN II
DIOSULFAN SULFATE	DIOSULFAN SULFATE
ENDRIN	ENDRIN
ENDRIN ALDEHYDE	ENDRIN ALDEHYDE
HEPTACHLOR	HEPTACHLOR
HEPTACHLOR EPOXIDE	HEPTACHLOR EPOXIDE
LINDANE (G-BHC)	LINDANE (G-BHC)
TOXAPHENE	TOXAPHENE
METHOXYCHLOR	METHOXYCHLOR
ENDRIN KETONE	ENDRIN KETONE
SULFUR GATE RECOVERY OBC:	

U indicates analyte not detected at or above detection limit shown
B indicates analyte detected in method blank associated with sample

Indicator or dilution was made

Indicator or dilution was made

SEDIMENT DATA
 Project: PINOLE SHOAL, WEST RICHMOND, RICHMOND
 Sponsor: SNOGGERDE

7/31/81

SEDIMENT PESTICIDE QUALITY CONTROL DATA

Sample Spiked: RH-SR-BAT

(Concentrations in ug/kg dry wt.)

PESTICIDE	Amount Spiked	Amount Recovered	Percent Recovered	Matrix Spike Duplicate Amount Spiked	Matrix Spike Duplicate Amount Recovered	Percent Recovered	CC Limits
ALDRIN	21.8	16.4	75%	20.7	15.6	65%	34-132
DIELDRIN	21.8	34	155% (A)	20.7	36	174% (A)	51-134
4,4-DDT	21.8	69	(A)	20.7	105	(A)	23-134
LINDANE (G-BHC)	21.8	14.3	65%	20.7	11.9	57%	48-127
ENDRIN	21.8	24	110%	20.7	30	145%	42-138
HEPTACHLOR	21.8	16.6	76%	20.7	13.5	65%	35-130
SURROGATE RECOVERY (DBP)			80%			80%	

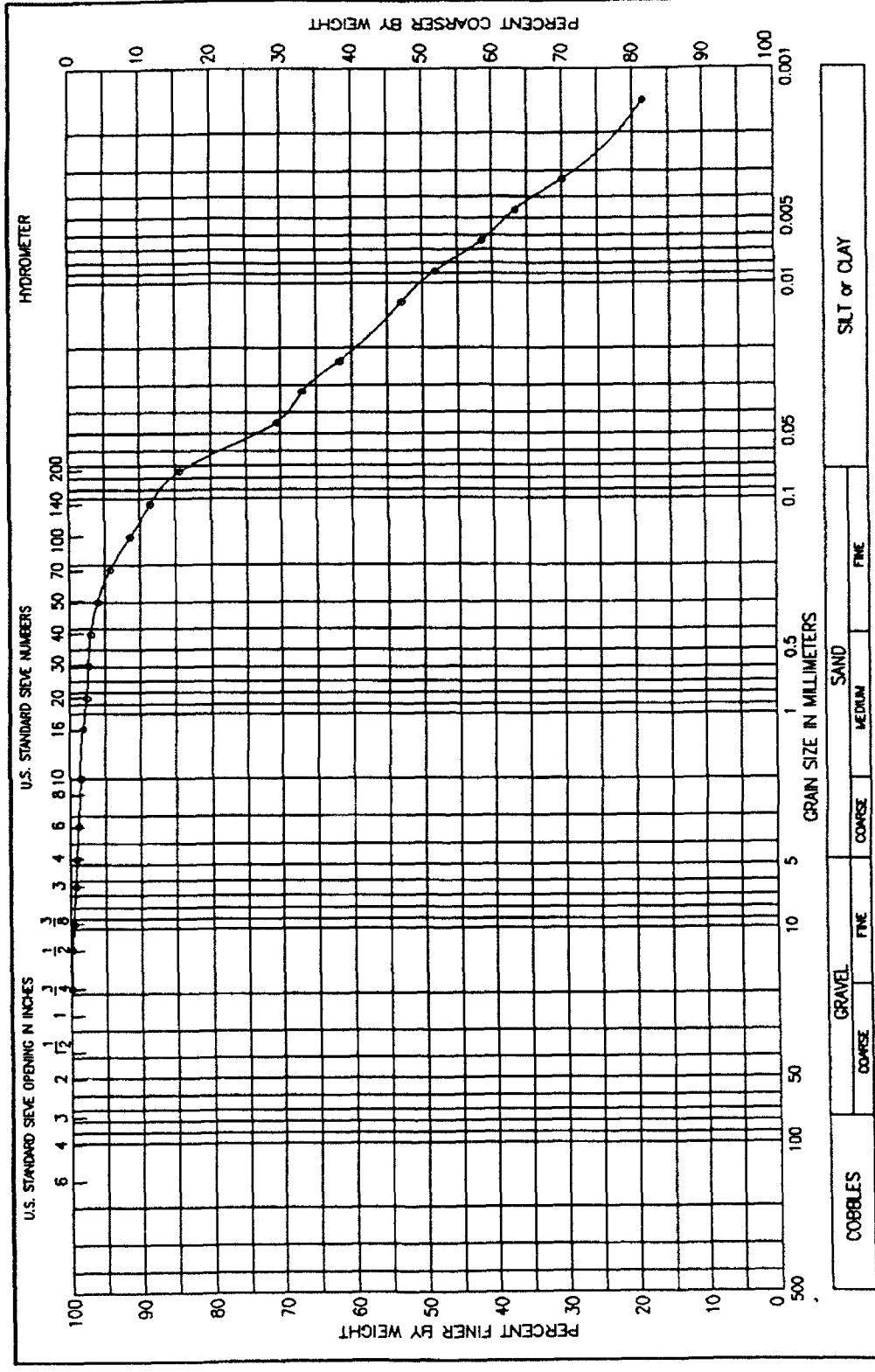
(A) Compound percent recovery outside of control limits due to high native concentrations.

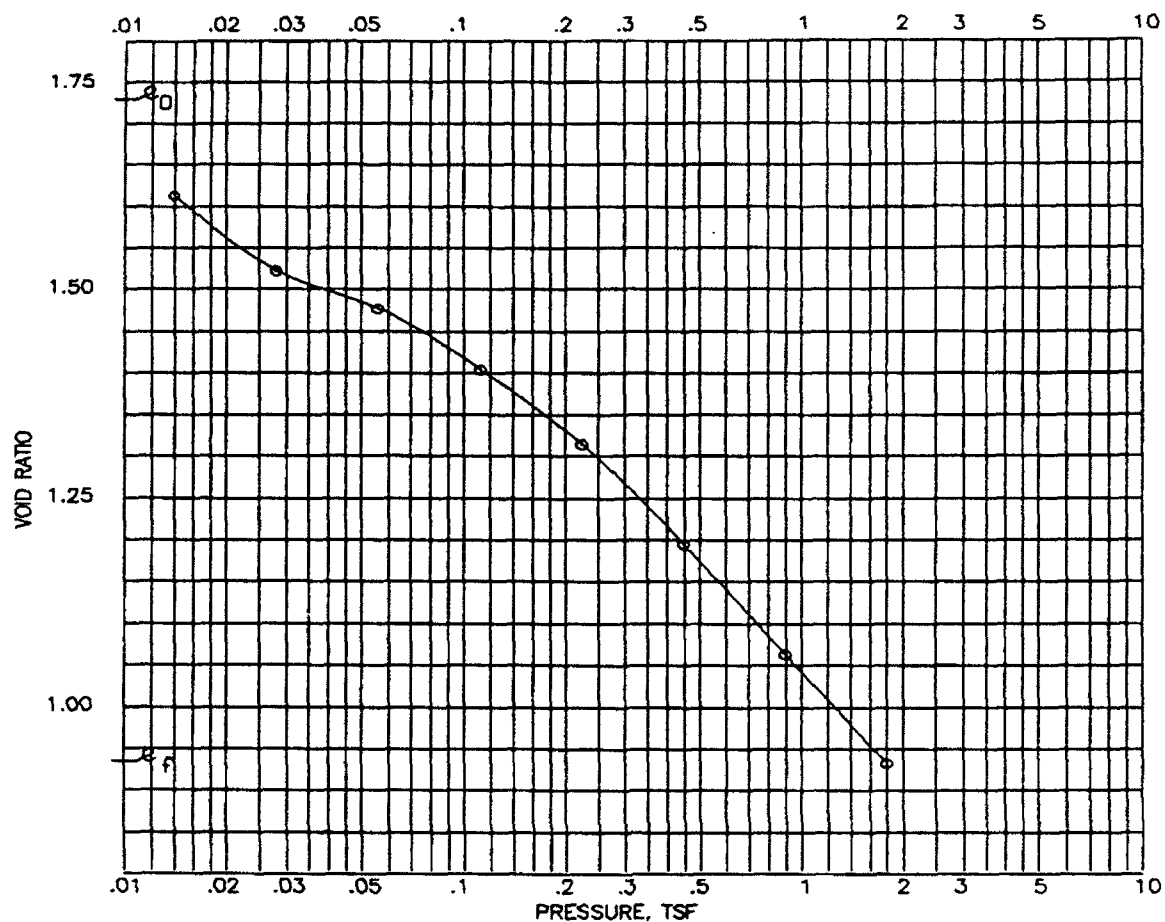
APPENDIX A
Sediment Physical Characterization

KEY

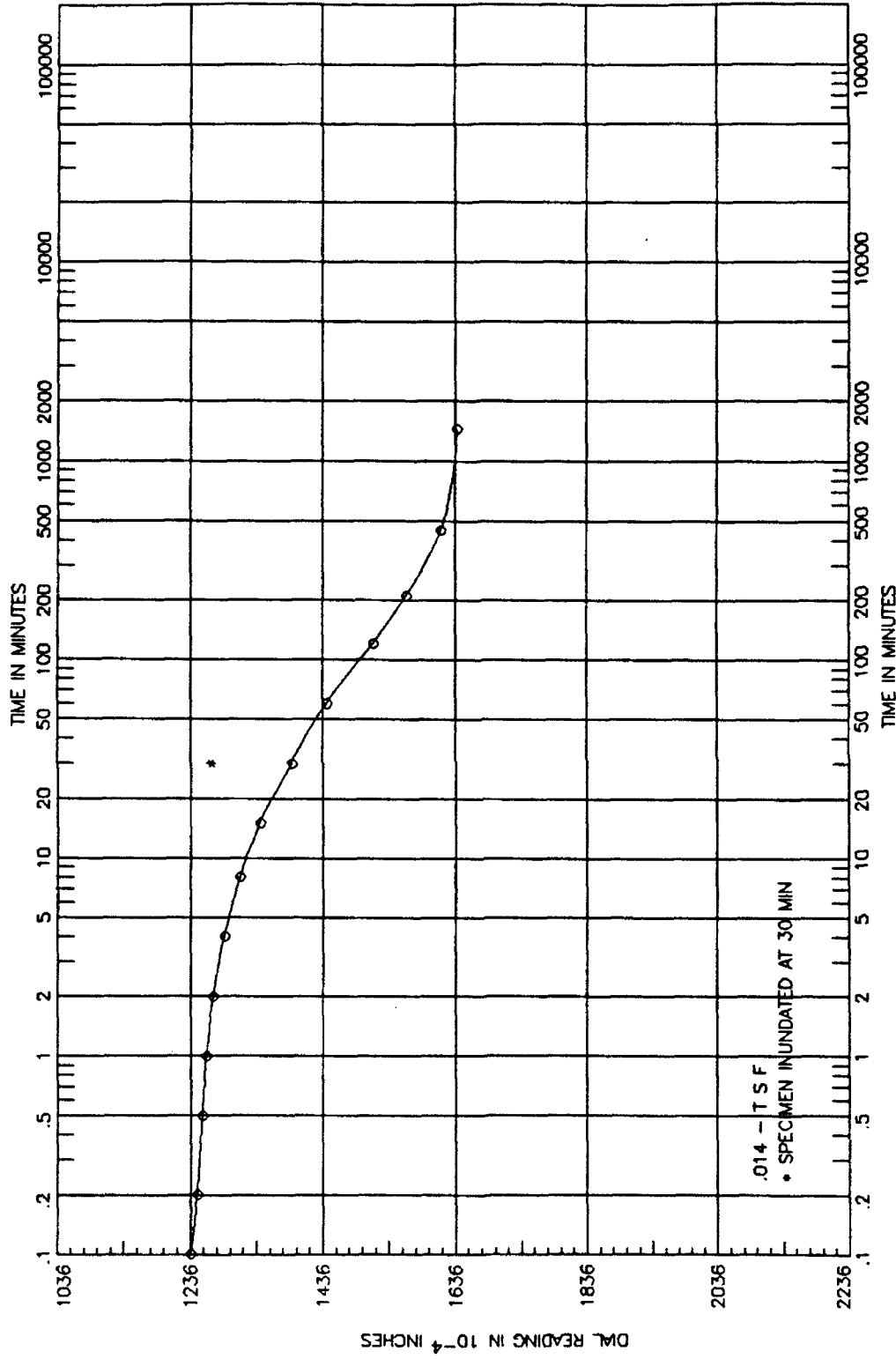
	<u>BORING NO.</u>	<u>SAMPLE NO.</u>
Santa Fe Channel Sediment -	RICHMOND	UPLAND

LL - Liquid Limit
PL - Plastic Limit
PI - Plasticity Index
GS - Specific Gravity
NAT W, % - % Water





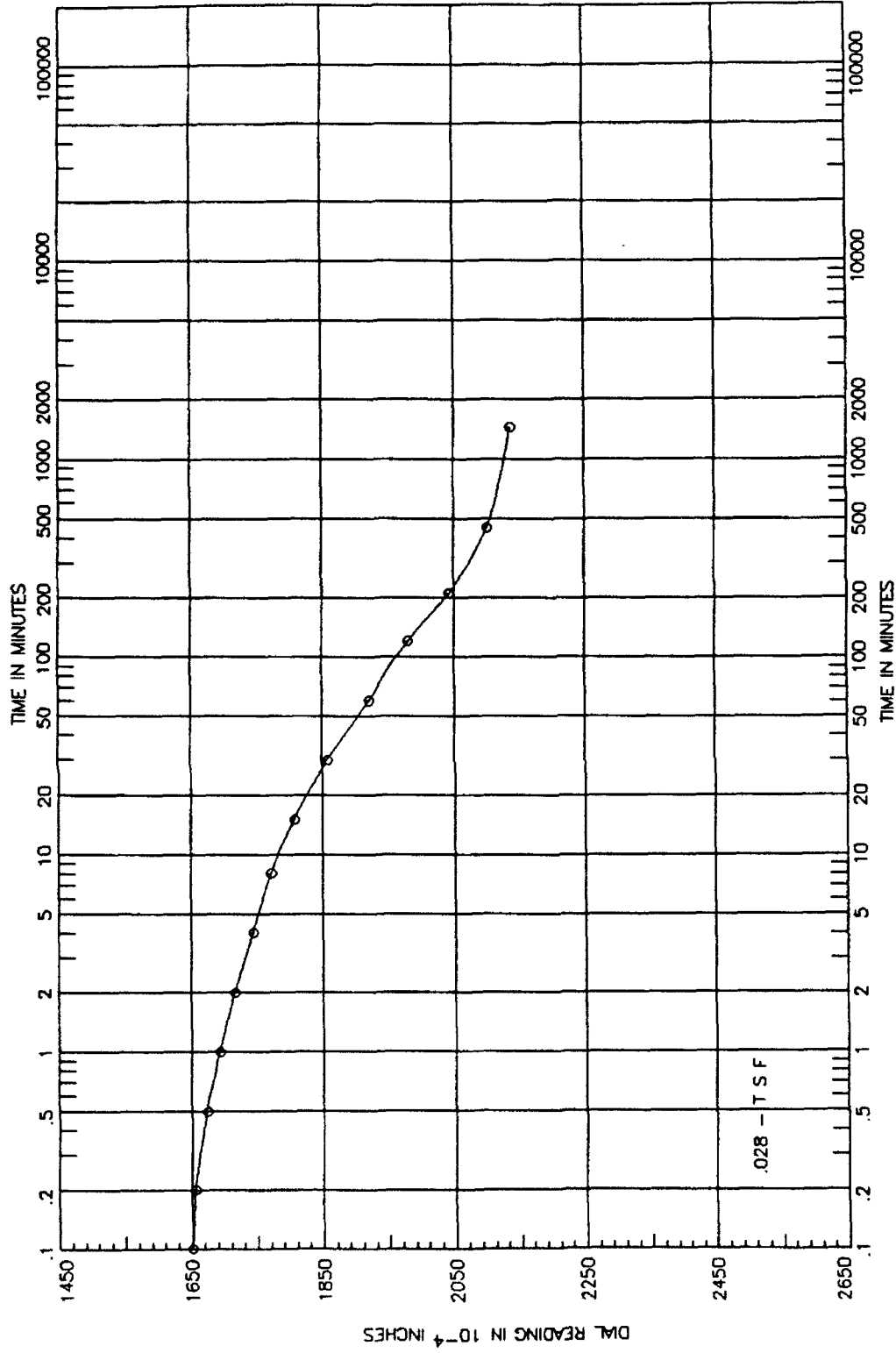
				BEFORE TEST	AFTER TEST	
OVERBURDEN PRESSURE, TSF			WATER CONTENT, %		59.7	37.3
PRECONSOL. PRESSURE, TSF			DRY DENSITY, PCF		62.5	88.2
COMPRESSION INDEX			SATURATION, %		94.4	100 +
TYPE SPECIMEN			VOID RATIO		1.728	.932
DIA. IN	2.50	HT. IN	1.500	BACK PRESSURE, TSF		
CLASSIFICATION SANDY CLAY (CH), GRAY						
LL	54	PL	25	PI	29	PROJECT
GS		2.73		D ₁₀		
REMARKS:				BORING NO. RICHMOND		SAMPLE NO. UPLAND
				DEPTH/ELEV LE		TECH. JAL
				LABORATORY USAE WES - STF/QL		DATE 04 JUN 91
				CONSOLIDATION TEST REPORT		



CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT	
BORING	RICHMOND
SAMPLE NO.	UPLAND
DEPTH/ELEV	LE
DATE	04 JUN 91



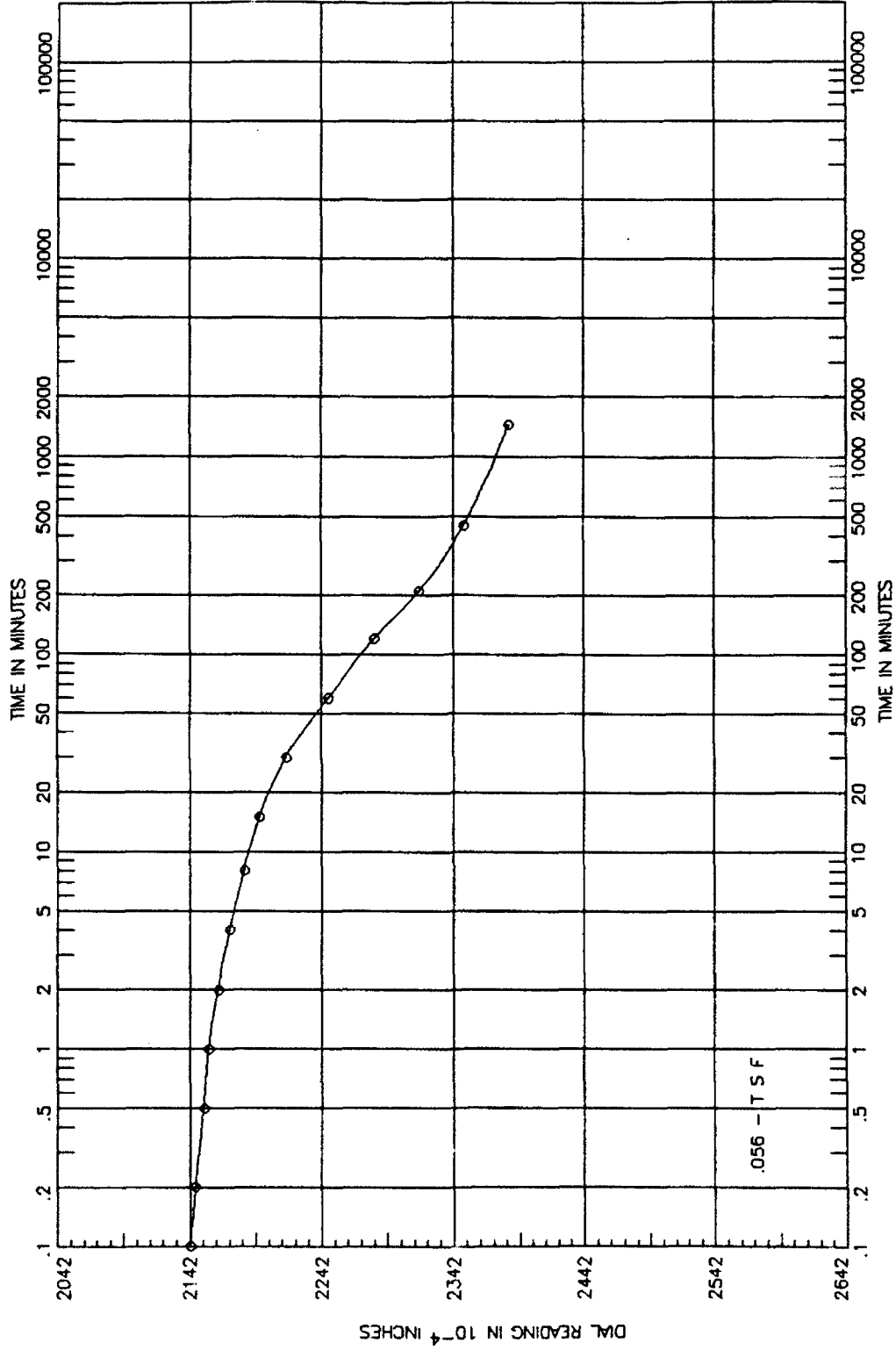
CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT

BORING RICHMOND SAMPLE NO. UPLAND

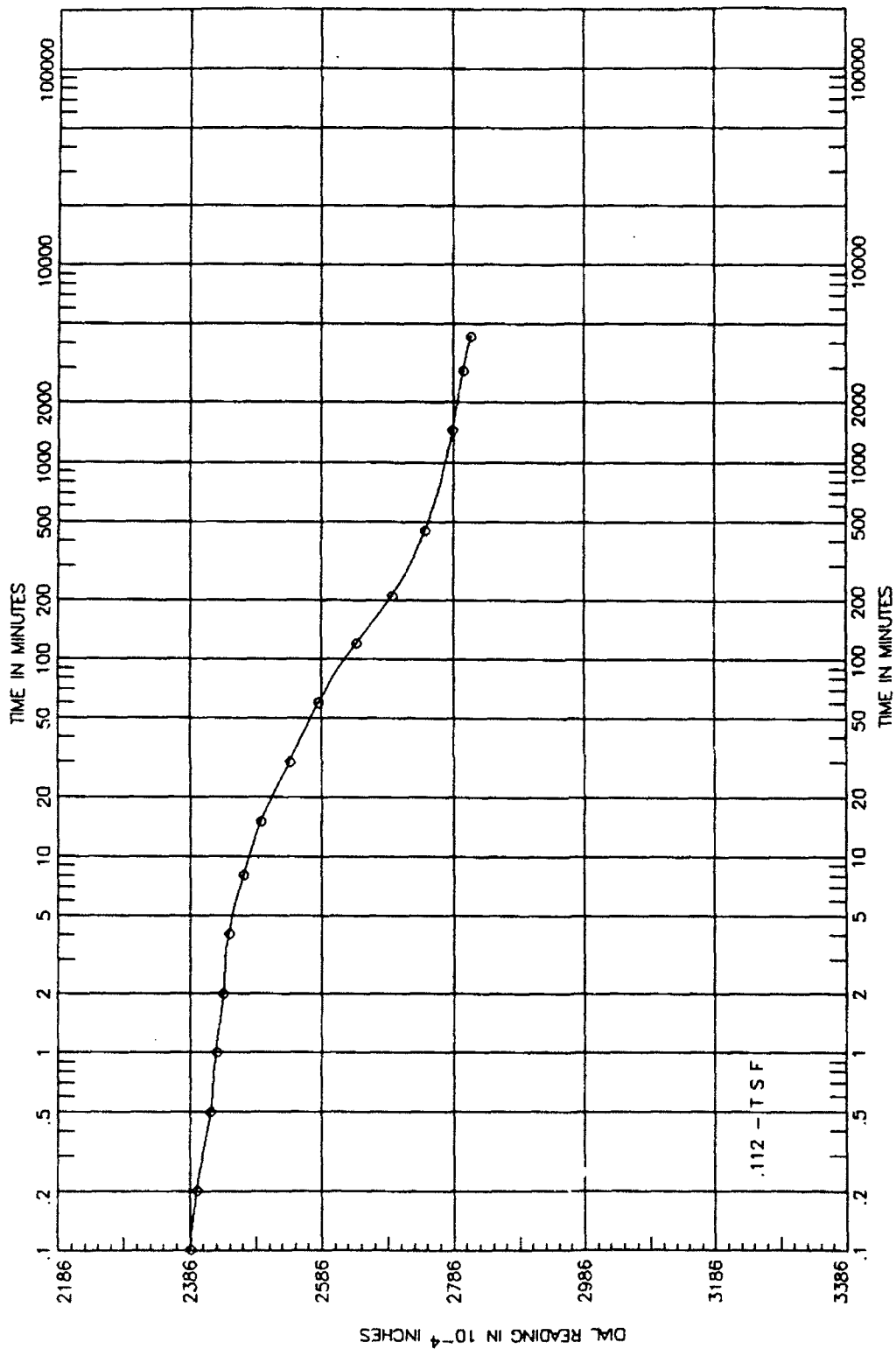
DEPTH/ELEV LE DATE 04 JUN 91



CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT	
BORING	RICHMOND
DEPTH/ELEV	LE
SAMPLE NO.	UPLAND
DATE	04 JUN 91



CONSOLIDATION TEST TIME CURVES

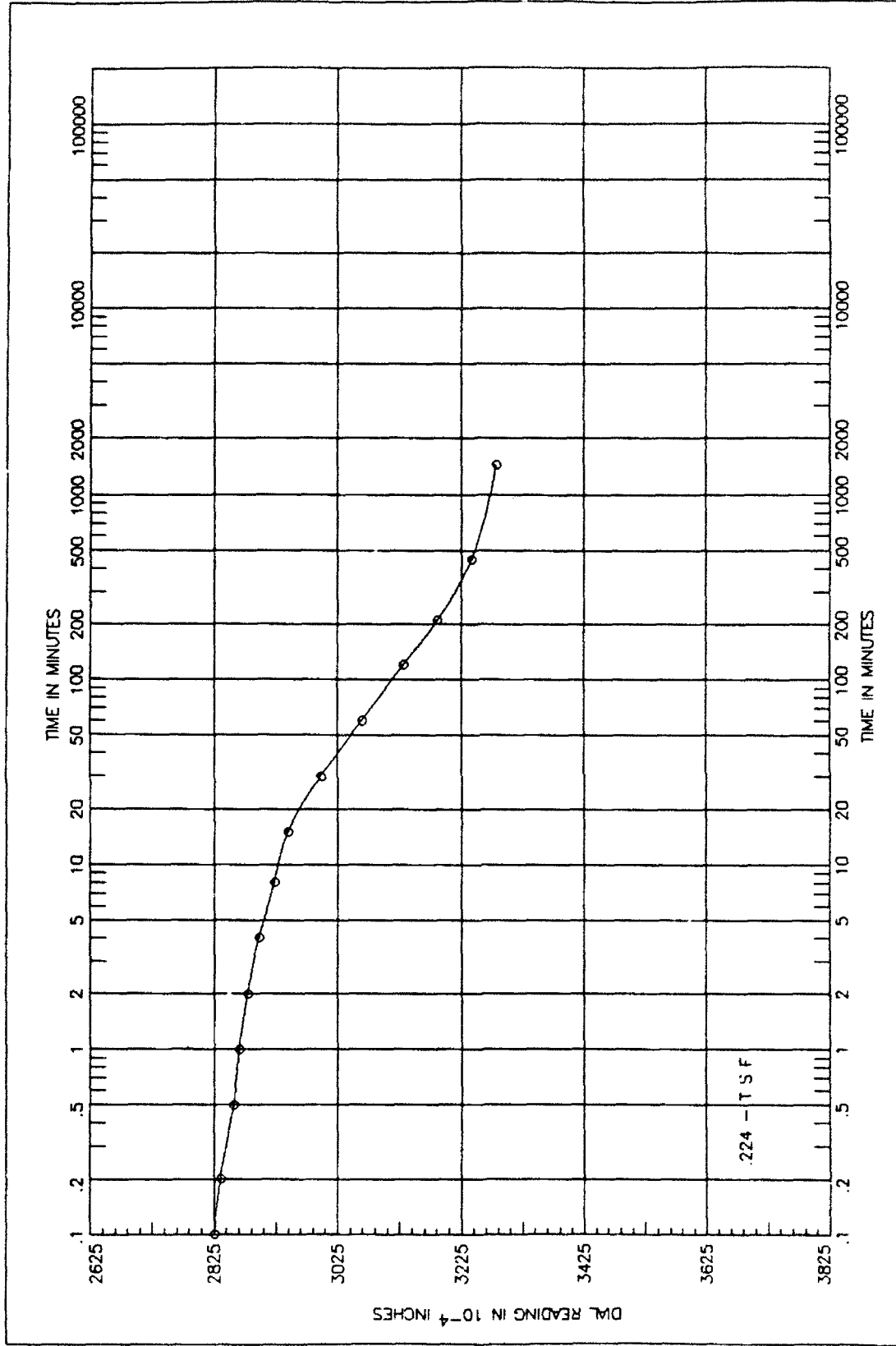
LABORATORY USAE WES - STF/GL

PROJECT

BORING RICHMOND SAMPLE NO. UPLAND

DEPTH/ELEV LE DATE 04 JUN 91

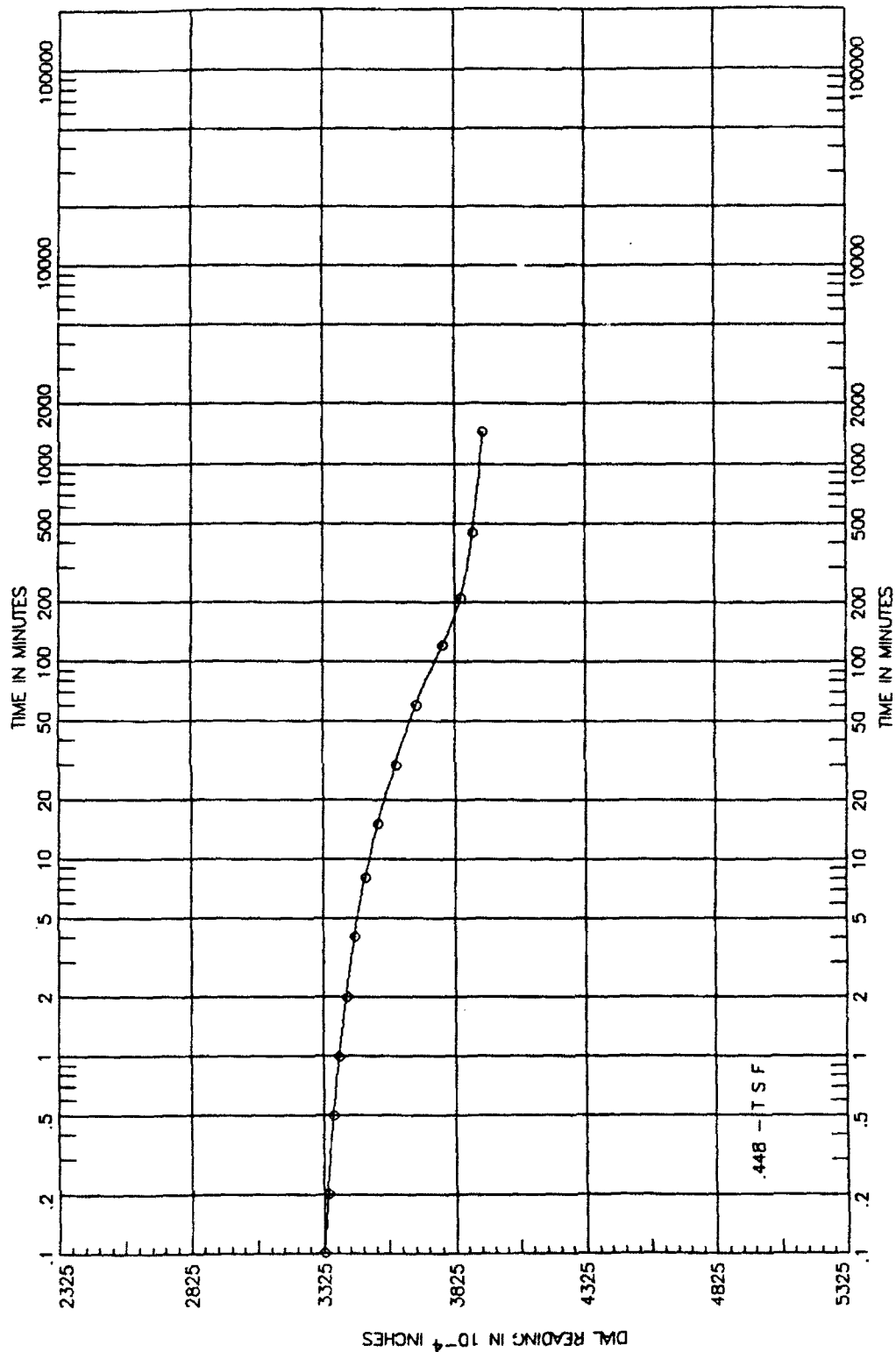
SHEET 5 OF 9



CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT		
BORING	RICHMOND	SAMPLE NO. UPLAND
DEPTH/ELEV	LE	DATE 04 JUN 91



CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/QL

PROJECT

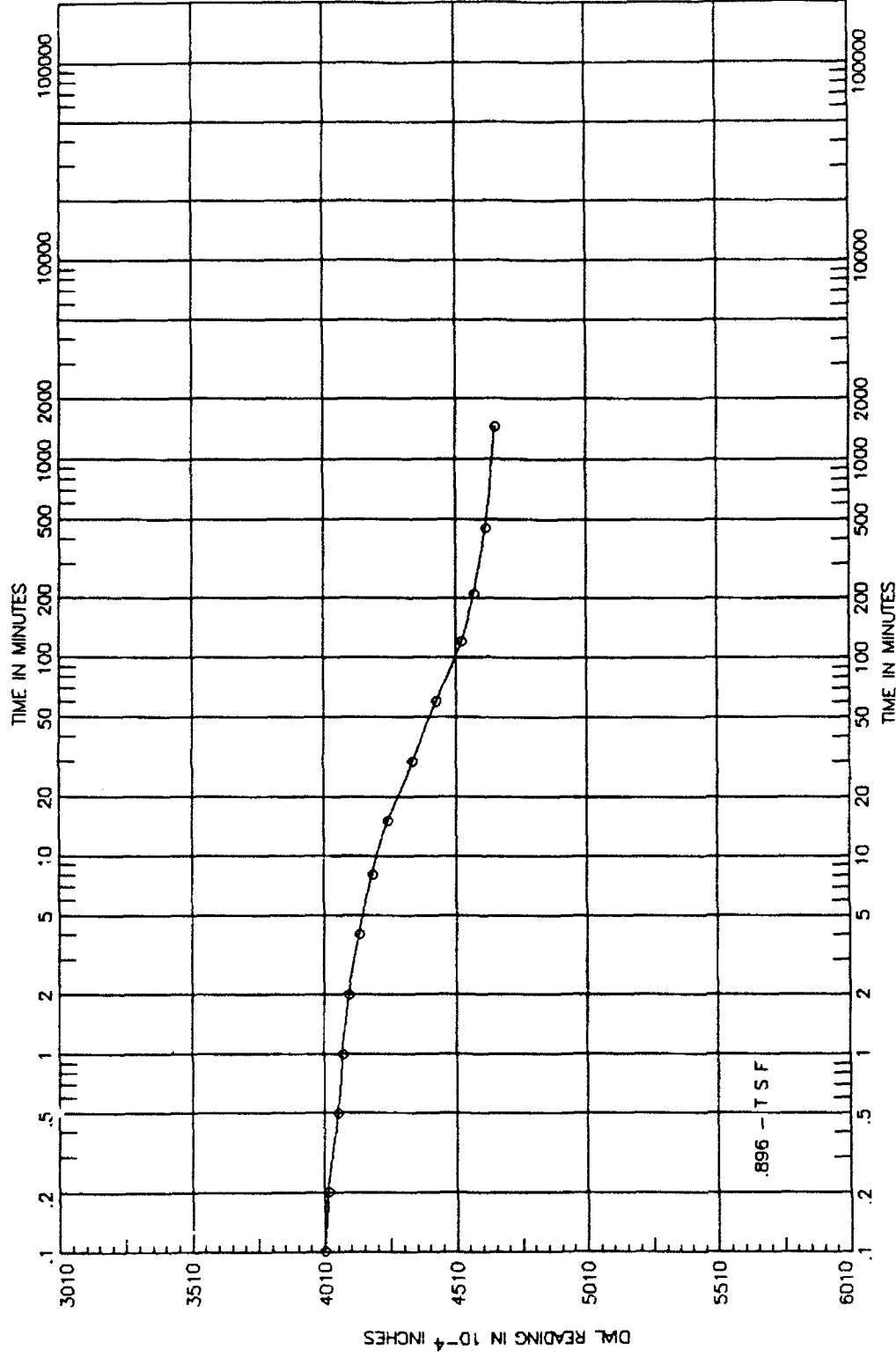
BORING RICHMOND

SAMPLE NO. UPLAND

DEPTH/ELEV LE

DATE 04 JUN 91

SHEET 7 OF 9



CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

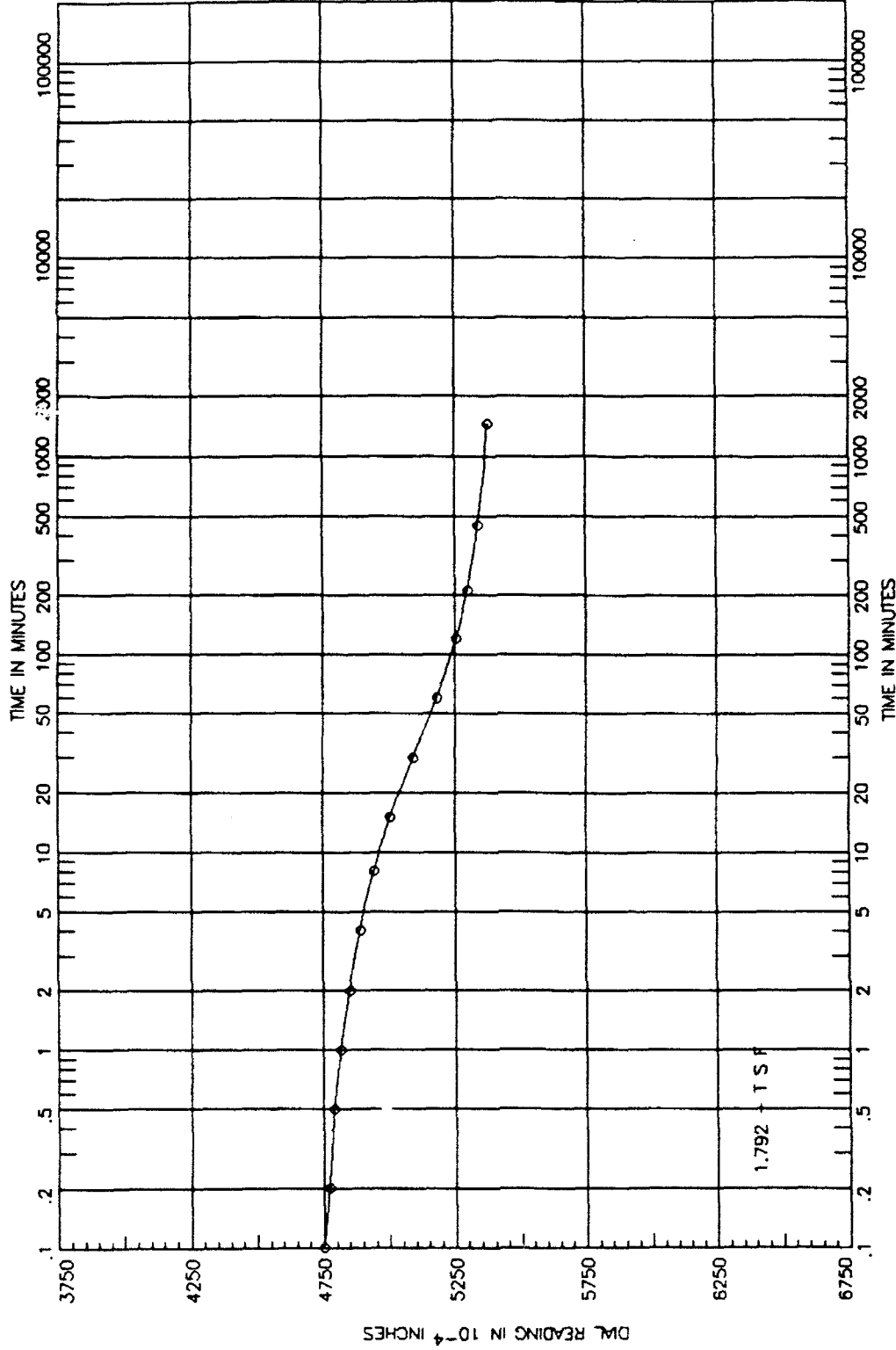
PROJECT

SAMPLE NO. UPLAND

BORING RICHMOND

DATE 04 JUN 91

DEPTH/ELEV LE



CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT

BORING RICHMOND SAMPLE NO. UPLAND

DEPTH/ELEV LE DATE 04 JUN 91

SHEET 9 OF 9

APPENDIX B: EFFLUENT TEST

KEY

	<u>Sponsor Code</u>	<u>Description</u>
Santa Fe Channel Sediment Elutriate	RISF-E-1- U	Rep 1, Unfiltered
	RISF-E-2- U	Rep 2, Unfiltered
	RISF-E-3- U	Rep 3, Unfiltered
	RISF-E-1- F	Rep 1, Filtered
	RISF-E-2- F	Rep 2, Filtered
	RISF-E-2- F	Rep 3, Filtered
	RISF-A U	QA/QC Duplicate
	RISF-B U	QA/QC Duplicate

244WATER

WATER DATA

Project: RICHMOND
Sponsor: TATEM

(CF#244)

6/7/91

WATER METAL DATA

(Concentrations in UG/L)

Bottle Code	Sponsor Code	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Sb	Zn
244-1	RISF-E-1-U	0.01	2.55	0.42	1.77	3.39	0.040	2.14	2.89	3.09 U	13.1
244-2	RISF-E-2-U	0.01	1.91	0.46	1.79	3.31	0.033	2.14	2.11	3.09 U	14.7
244-3	RISF-E-3-U	0.01 U	3.82	0.39	1.63	3.03	0.014	1.91	1.89	3.09 U	12.8
244-4	RISF-E-1-F	0.01	1.91	0.68	0.58	5.75	0.051	1.18	2.83	3.09 U	28.5
244-5	RISF-E-2-F	0.01	3.18	0.68	3.18	4.50	0.054	1.23	2.22	3.09 U	28.3
244-6	RISF-E-3-F	0.01	3.82	0.74	0.57	4.50	0.014	1.18	1.60	3.09 U	28.9
244-7	RISF-A U	0.01	1.91 U	0.21	0.64	3.05	0.019	1.35	1.14	3.09 U	17.0
244-8	RISF-B U	0.01	1.91	0.23	0.73	3.10	0.050	1.57	1.22	3.09 U	15.1

STANDARD REFERENCE MATERIAL

1841

CERTIFIED VALUES:

1.48
1.52
±0.04

CERTIFIED VALUES:

0.033 U
0.019
±0.006

CASS-2

0.01 U
NC

0.127
0.121
±0.016

0.765
0.675
±0.039

NA
NC

0.303
0.298
±0.36

2.57
1.97
±0.12

CERTIFIED VALUES:

0.01 U
NC

0.019
0.015
±0.002

3.51
3.58
±0.3

NA
NC

0.101
0.106
±0.011

NA
NC

* Detection limits elevated due to saltwater interferences.

U indicates not detected at detection limit shown

NA indicates not analyzed

NC indicates not certified

244WATER

WATER DATA
Project:
Sponsor:

RICHMOND
TATEM

(CF#244)

3/15/91

WATER BUTYLIN RESULTS

(Concentrations in ng/L; ppt)

Sample Code	Sponsor Code	TETRA-BUTYLIN	TRI-BUTYLIN	DI-BUTYLIN	MONO-BUTYLIN	% Surrogate Recovery PROPYLIN
244-17	RISF-E-7-U	3.6 U	14.3 B	5.3	3.6	28%
244-18	RISF-E-8-U	10.6 U	11.8 U	10.1 U	9.8 U	41%
244-19	RISF-E-9-U	2.9 U	14.5 B	5.7	3.6	42%
244-20	RISF-E-7-F	3.2 U	14.8 B	10.9	4.0	49%
244-21	RISF-E-8-F	13.8 U	15.5 U	13.2 U	12.8 U	45%
244-22	RISF-E-9-F	11.8 U	13.0 U	12.2	10.7 U	54%
244-23	RISF-SI-A-U	3.5 U	14.6 B	28.5	3.9	54%
244-24	RISF-SI-B-U	11.4 U	16.7 B	10.9 U	10.6 U	41%
METHOD BLANK		8.5 U	12.3	8.1 U	7.8 U	49%

AMOUNT SPIKED: 222 NG/L
AMOUNT RECOVERED: 33
PERCENT RECOVERY: 15%

U indicates not detected at detection limit shown.
B indicates analyte detected in method blank

244WATER

WATER DATA
Project:
Sponsor:

RICHMOND
TATEM

(CF#244)

3/15/91

WATER PAH DATA

(Concentrations in ng/L)

Sponsor Code
Bottle Code: 244-9

RISF-E-4-U
244-10

RISF-E-5-U
244-11

RISF-E-6-U
244-12

RISF-E-4-F
244-13

RISF-E-5-F
244-14

RISF-E-6-F
244-15

RISF-SI-A
244-16

RISF-SI-B
244-16

METHOD
BLANK

NAPHTHALENE	38.5 U
ACENAPHTHYLENE	5.9 U
ACENAPHTHENE	14.6 U
FLUORENE	11.7 U
PHENANTHRENE	15.6 U
ANTHRACENE	6.8 U
FLUORANTHENE	9.8 U
PYRENE	14.1
BENZANTHRACENE	6.8 U
CHRYSENE	6.4
BENZO [B] FLUORANTHENE *	7.3 U
BENZO [A] PYRENE	5.9 U
INDENO [1,2,3-cd] PYRENE	9.3 U
DIBENZ [a,h] ANTHRACENE	5.4 U
BENZO [ghi] PERYLENE	4.7 U
SURROGATE RECOVERY:	
D10-FLUORENE	82%
D10-ANTHRACENE	92%
D10-PYRENE	89%

39.5 U	37.0 U	37.6 U	37.8 U	37.6 U	37.8 U	38.1 U	31.6 U
6.0 U	5.6 U	5.7 U	5.7 U	5.7 U	5.8 U	5.8 U	4.8 U
45.0 U	14.0 U	14.3 U	14.3 U	14.3 U	14.4 U	14.5 U	12.0 U
12.0 U	11.2 U	11.4 U	11.4 U	11.4 U	11.5 U	11.6 U	9.6 U
16.0 U	15.0 U	15.2 U	15.2 U	15.2 U	15.3 U	15.4 U	12.8 U
7.0 U	6.6 U	6.7 U	6.7 U	6.7 U	6.7 U	6.8 U	5.6 U
10.0 U	9.4 U	9.5 U	9.5 U	9.5 U	9.6 U	9.6 U	8.0 U
14.9	13.4	7.1 U	7.1 U	7.1 U	7.2 U	7.2 U	6.0 U
7.0 U	6.6 U	6.7 U	6.7 U	6.7 U	6.7 U	6.8 U	5.6 U
6.0 U	5.6 U	5.7 U	5.7 U	5.7 U	5.8 U	5.8 U	4.8 U
7.5 U	7.0 U	7.1 U	7.1 U	7.1 U	7.2 U	7.2 U	6.0 U
6.0 U	5.6 U	5.7 U	5.7 U	5.7 U	5.8 U	5.8 U	4.8 U
9.5 U	8.9 U	9.1 U	9.1 U	9.1 U	9.1 U	9.2 U	7.6 U
5.5 U	5.2 U	5.2 U	5.2 U	5.2 U	5.3 U	5.3 U	4.4 U
4.8 U	4.5 U	4.6 U	4.6 U	4.6 U	4.6 U	4.6 U	3.8 U

80%
85%
95%

51%
73%
88%

55%
76%
85%

82%
84%
90%

55%
78%
83%

81%
94%
92%

76%
93%
89%

U indicates analyte not detected at or above detection limit shown
* All benzofluoranthene isomers are quantified together

APPENDIX C: SURFACE RUNOFF TEST

KEY

	<u>Sponsor Code</u>	<u>Description</u>
Santa Fe Channel Sediment Runoff	RIW-1-MU	Rep 1, Metals, Unfiltered
	R1W-1-MF	Rep 1, Metals, Filtered
	R1W-2-MU2	Rep 2, Metals, Unfiltered, Duplicate
	R1W-2-MU3	Rep 2, Metals, Unfiltered, Method Blank

227WATER

WATER DATA (CF#227) 2/7/91

Project: RICHMOND HARBOR
Sponsor: SNOGEBOE

WATER METAL DATA

(Concentrations in UG/L)

Battelle Code	Sponsor Code	Ag	As	Cd	Cf	Cr	Cu	Hg	Ni	Pb	Sb	Zn
ACID BLANK												
227-3	RIW-1-MU	0.04	1.0 U	0.1 U	0.5	42.7	289	1 U	0.1 U	0.1	1.0 U	1 U
227-4	RIW-1-MF	0.14	13.4	4.2	42.7	2.3	1 U	0.72	171	86.5	4.9	631
227-5	RIW-2-MU1	0.05	2.5	0.1 U	10.5	10.5	214	0.1 U	1 U	0.3	4.0	15
227-6	RIW-2-MU2	0.07	10.6	3.1	45.1	1.2	367	0.1 U	1 U	36.1	5.4	566
227-7	RIW-2-MF1	0.05	20.1	3.7	1.2	1.5	1 U	0.1 U	1 U	71.6	8.5	685
227-8	RIW-2-MF2	0.13	3.9	0.1 U	0.6	0.8	1 U	0.1 U	1 U	0.6	5.7	12
227-11	RIW-2-MU3	0.04	5.2	0.1 U	1.5	34.7	235	0.1 U	1 U	0.4	1.9	16
227-18	RIW-3-MU1	0.05	1.0 U	0.1 U	0.6	1.5	1 U	0.1 U	1 U	0.5	1.0 U	1
227-19	RIW-3-MF1	0.07	12.5	2.8	0.1 U	1.5	1 U	0.1 U	1 U	61.3	4.9	521
227-20	RIW-3-MU3	0.08	3.3	0.1 U	0.5	0.5	1 U	0.1 U	1 U	0.7	2.5	10
		0.03	1.0 U	0.1 U	0.5	0.5	1 U	0.1 U	1 U	1.6	1.0 U	1

* Initial values not acceptable due to C+ interferences. Currently being reanalyzed by GFAA.

.. Hg currently being analyzed by CVAA.

MATRIX SPIKE

227-8 + SPIKE
AMOUNT RECOVERED
% RECOVERIES
NS indicates not spiked

0.18	139	8	13	NS	4	8	16	542
0.05	100	10	10		10	10	10	500
28%	72%	124%	80%		282%	123%	61%	92%

STANDARD REFERENCE MATERIAL

1643 REP 1
1643 REP 2
CERTIFIED VALUES:
NC indicates not certified

10.4	60.2	19.4	19.5		49.8	23.5	7.2	66.5
10.5	62.6	19.1	18.9		46.6	23.6	10.1	68.4
9.8	-49	20.0	18.6	NC	49.0	23.7	9.7	66.0

227WATER

WATER DATA
Project: RICHMOND HARBOR
Sponsor: SNOGERBOE

2/7/91

(CF#227)

WATER PAH DATA

(Concentrations in ng/L)

Sponsor Code: 227-1	227-1	227-2	227-9	227-10	227-12	227-13	227-14	227-15	227-16	227-17
Bottle Code: RIW-1-OU1	RIW-1-OU1	RIW-1-OF	RIW-2-OU	RIW-2-OF	RIW-2-OU3	RIW-3-OU1	RIW-3-OU2	RIW-3-OU3	RIW-3-OF1	RIW-3-OF2
NAPHTHALENE	49 U	48 U	41 U	41 U	41 U	37 U	40 U	39 U	39 U	41 U
ACENAPHTHYLENE	7.5 U	7.2 U	6.2 U	6.2 U	6.2 U	5.6 U	6.1 U	5.9 U	5.9 U	6.2 U
ACENAPHTHENE	19 U	18 U	15 U	15 U	16 U	14 U	15 U	15 U	15 U	16 U
FLUORENE	15 U	14 U	12 U	12 U	12 U	11 U	12 U	12 U	12 U	12 U
PHENANTHRENE	20 U	33	16 U	49	17 U	15 U	45	16 U	58	49
ANTHRACENE	8.8 U	17	7.2 U	23	7.3 U	6.5 U	9	6.9 U	13	7.6
FLUORANTHENE	13 U	75	21	86	10 U	18	23	10 U	53	18
PYRENE	25	171	50	190	7.8 U	47	51	7.4 U	120	38
BENZANTHRACENE	8.8 U	50	15	59	7.3 U	12	15	6.9 U	45	10
CHRYSENE	7.5 U	64	11	49	8.2 U	9.4	11	5.9 U	37	6.2 U
BENZO (K) FLUORANTHENE	40	315	69	380	7.8 U	66	94	7.4 U	230	49
BENZO (B) FLUORANTHENE	.	.	.	.	.	.	.	.	.	.
BENZOPYRENE	14	150	31	150	8.2 U	27	31	5.9 U	100	19
INDENO (1,2,3-cd) PYRENE	12 U	74	10	57	9.9 U	8.8 U	9.6 U	9.4 U	35	9.9 U
DBENZO (a,j) ANTHRACENE	6.9 U	11	5.6 U	5.7 U	5.7 U	5.1 U	5.6 U	5.5 U	5.4 U	5.7 U
BENZODIPIPERYLENE	6 U	120	17	93	5 U	9.8 U	12	4.8 U	57	5 U
SURROGATE RECOVERY:										
D10-FLUORENE	40%	51%	56%	89%	88%	35%	89%	81%	30%	88%
D10-ANTHRACENE	41%	68%	67%	97%	89%	58%	92%	80%	62%	88%
D10-PYRENE	40%	78%	84%	88%	88%	85%	82%	92%	81%	85%

U indicates analyte not detected at or above detection limit shown
 . All benzofluoranthene isomers are quantified together

227WATER

WATER DATA

Project: RICHMOND HARBOR
Sponsor: SKOGERBOE

(CF#227)

2/7/91

WATER PESTICIDE DATA

PESTICIDES	(Concentrations in ug/L)									
	227-1 RIW-1-OU1	227-2 RIW-1-OF	227-9 RIW-2-OU	227-10 RIW-2-OF	227-12 RIW-2-OU3	227-13 RIW-3-OU1	227-14 RIW-3-OU2	227-15 RIW-3-OU3	227-16 RIW-3-OF1	227-17 RIW-3-OF2
Battelle Code:	227-1	227-2	227-9	227-10	227-12	227-13	227-14	227-15	227-16	227-17
Sponsor Code:	RIW-1-OU1	RIW-1-OF	RIW-2-OU	RIW-2-OF	RIW-2-OU3	RIW-3-OU1	RIW-3-OU2	RIW-3-OU3	RIW-3-OF1	RIW-3-OF2
TCT Code:										
ALDRIN	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
A-BHC	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
B-BHC	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
D-BHC	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
CHLORDANE	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
4,4'DDD	1.8 D	3.1 D	1.9 D	2.2 D	0.06 U	1.2 D	1.3 D	0.06 U	1.5 D	0.8
4,4'DDE	0.3	0.4	0.2	0.2	0.06 U	0.2	0.2	0.06 U	0.3	0.2
4,4'DDT	0.4	2.1	0.4	3.1 D	0.06 U	0.4	0.4	0.06 U	0.8	0.4
DELDRIN	0.06 U	0.06 U	0.3	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
ENDOSULFAN I	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
ENDOSULFAN II	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
EDOSULFAN SULFATE	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
ENDRIN	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
ENDRIALDEHYDE	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.07
HEPTACHLOR	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
HEPTACHLOR EPOXIDE	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
LINDANE (G-BHC)	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
TOXAPHENE	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
METHOXYCHLOR	0.12 U	0.12 U	0.12 U	0.12 U	0.12 U	0.12 U	0.12 U	0.12 U	0.12 U	0.12 U
ENDRIN KETONE	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
SURROGATE RECOVERY (DBCL)	111%	128%	90%	100%	102%	108%	113%	124%	111%	122%

D Indicates analysis was performed on diluted sample.

227WATER

WATER DATA
Project: RICHMOND HARBOR
Sponsor: SKOGERBOE

(CF#227)

3/15/91

WATER BUTYL TIN RESULTS

(Concentrations in ng/L; ppb)

Sample Code	Sponsor Code	TETRA-BUTYL TIN	TRI-BUTYL TIN	DI-BUTYL TIN	MONO-BUTYL TIN	% Surrogate Recovery PROPYL TIN
METHOD BLANK						
227-1	RIW-1-OU1	5 U	29	5 U	6 U	109%
227-2	RIW-1-OF	N/A	N/A	N/A	N/A	
227-9	RIW-2-OU	5 U	28 B	5 U	6 U	85%
227-10	RIW-2-OF	6	81 B	40	11	48%
227-12	RIW-2-OF	5 U	36 B	6	6 U	88%
227-13	RIW-3-OU1	5 U	31 B	5 U	6 U	90%
227-14	RIW-3-OU2	5 U	77 B	45	14	49%
227-15	RIW-3-OU3	5 U	84 B	34	12	36%
227-16	RIW-3-OF1	5 U	27 B	26	6 U	84%
227-17	RIW-3-OF2	5 U	35 B	5 U	6 U	85%
		5 U	31 B	7	6 U	86%

Matrix Spike (Spiked with 400 ng/L)

296

399

108

18

101%

PERCENT RECOVERY:

73%

93%

26%

NS

N/A Indicates data not available. Due to contamination of initial sample, no sample was left for re-analyses.

U Indicates not detected at detection limit shown.

B Indicates analyte detected in method blank

WATER DATA

Project: RICHMOND HARBOR
Sponsor: SMOGEBOE

(CF#227)

2/7/91

WATER PESTICIDE QUALITY CONTROL DATA

Bottle Code:
Sponsor Code:
TCT Code:

METHOD BLANK

(Concentrations in ug/L)

PESTICIDES	0.06 U
ALDRIN	0.06 U
A-BHC	0.06 U
B-BHC	0.06 U
D-BHC	0.06 U
CHLORDANE	0.06 U
4,4'DDD	0.06 U
4,4'DDE	0.06 U
4,4'DDT	0.06 U
DIELDRIN	0.06 U
ENDOSULFAN I	0.06 U
ENDOSULFAN II	0.06 U
EDOSULFAN SULFATE	0.06 U
ENDRIN	0.06 U
ENDRIALDEHYDE	0.06 U
HEPTACHLOR	0.06 U
HEPTACHLOR EPOXIDE	0.06 U
LINDANE (G-BHC)	0.06 U
TOMAPHENE	0.6 U
METHOXYCHLOR	0.12 U
ENDRIN KETONE	0.06 U
SURROGATE RECOVERY (DBC)	123%

Sample Spiked:

Amount Spiked	MATRIX SPIKE Amount Recovered	Percent Recovered	MATRIX SPIKE DUPLICATE Amount Spiked	Amount Recovered	Percent Recovered
0.72	0.19	26%	0.72	0.25	30%
NS			NS		
NS			NS		
NS			NS		
NS			NS		
NS			NS		
NS			NS		
NS			NS		
NS			NS		
0.72	0.3	42%	0.72	0.3	42%
0.72	0.48	67%	0.72	0.6	83%
NS			NS		
NS			NS		
NS			NS		
0.72	0.48	67%	0.72	0.46	64%
NS			NS		
0.72	0.31	43%	0.72	0.28	39%
NS			NS		
0.72	0.33	46%	0.72	0.34	47%
NS			NS		
NS			NS		
NS			NS		
		121%			116%

NS indicates analyte not spiked
U indicates analyte not detected at or above detection limit shown

227WATER

WATER DATA
Project: RICHMOND HARBOR
Sponsor: SNOGERBOE

(CF#227)

2/7/81

WATER PAH QUALITY CONTROL DATA

(Concentrations in ng/L)	METHOD BLANK	Sample Spiked: 227-1 (RIW:10U)				MATRIX SPIKE				MATRIX SPIKE DUPLICATE			
		Amount Spiked	Amount Recovered	Percent Recovered	Percent Recovered	Amount Spiked	Amount Recovered	Percent Recovered	Percent Recovered	Amount Spiked	Amount Recovered	Percent Recovered	Percent Recovered
NAPHTHALENE	34 U	787	340	43% **	45% **	719	540	75%	75%	719	540	75%	75%
ACENAPHTHYLENE	5.2 U	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
ACENAPHTHENE	13 U	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
FLUORENE	10 U	787	465	59%	59%	719	607	84%	84%	719	607	84%	84%
PHENANTHRENE	14 U	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
ANTHRACENE	6.1 U	787	555	70%	70%	719	677	94%	94%	719	677	94%	94%
FLUORANTHENE	8.7 U	787	707	90%	90%	719	718	100%	100%	719	718	100%	100%
PYRENE	6.5 U	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BENZ[A]ANTHRACENE	6.1 U	787	817	104%	104%	719	769	107%	107%	719	769	107%	107%
CHRYSENE	5.2 U	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BENZO[B]FLUORANTHENE	6.5 U	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BENZ[B]FLUORANTHENE	5.2 U	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BENZ[OKP]THENE	8.3 U	787	948	119%	119%	719	920	128%	128%	719	920	128%	128%
INDENOT[1,2,3-cd]PYRENE	4.8 U	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BENZ[OKP]ANTHRACENE	4.2 U	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BENZ[OKP]PERYLENE	4.2 U	787	1098	138%	138%	719	1005	139%	139%	719	1005	139%	139%

SURROGATE RECOVERY:

D10-FLUORENE 81%
D10-ANTHRACENE 90%
D10-PYRENE 79%

NS indicates analyte not spiked
U indicates analyte not detected at or above detection limit shown
** indicates outside of control limits (control limits: 50 - 150 %)

APPENDIX D: LEACHATE TEST

KEY

Sediment : R - Richmond Harbor

Condition : AN - Anaerobic
A - Aerobic

Type : S - Sequential Extract
K - Kinetic Extract

Day : D - 1 through 10. Day 1 through Day 10

Column Leachate Sample: 1 through 26

Parameter : MET - Metals
PAH - Petroleum aromatic hydrocarbons
TBT - Butyltins
PEST - Pesticides
O - Organics
M - Metals

Examples:

RANK TBT D1-1 : Richmond, Anaerobic, Kinetic, Tributyltin, day 1, Rep 1

RANS PAH D5-3 : Richmond, Anaerobic, Sequential, PAHs, day 5, Rep 3.

RO-14-5: Richmond, Organics, Columnn 14, leachate sample 5.

RM-7-20: Richmond, Metals, Column 7, leachate sample 20.

1/8/92

WES RICHMOND (CF #322)
WATER METAL RESULTS
(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As AA	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
1% HNO3		1 U	0.01 U	1 U	1 U	NA	NA	0.03	0.01 U	NA	1 U
322-35	RM-7-14	30.7	35.4	55.5	64.5	18.13	1.08 U	0.08	0.42	0.00104	20.4
322-36 Rep 1	RM-7-15	57.5	48.7	90.3	80.5	16.70	1.08 U	1.05	0.07	0.25956	36.1
322-36 Rep 2	RM-7-15	61.5	50.2	94.4	90.8	17.66	1.08 U	0.87	0.38	0.25221	36.7
322-37	RM-7-16	67.1	79.2	134	161	21.95	1.08 U	0.18	1.23	0.00247	49.1
322-38	RM-7-17	97.0	113	192	237	21.00	1.08 U	0.18	1.51	0.00397	74.8
322-39	RM-7-18	NA	NA	NA	NA	34.83	1.22	NA	NA	0.09396	NA
322-40	RM-7-19	135	191	307	400	19.56	1.08 U	0.04	2.82	0.00034	131
322-41	RM-7-20	289	277	438	515	20.04	1.22	1.86	2.90	0.23456	178
322-42	RM-7-21	207	215	329	413	18.61	1.83	0.53	2.08	0.01548	142
322-43	RM-7-22	142	164	251	339	15.75	1.22	0.17	2.36	0.02258	109
322-44	RM-7-24	26.8	38.2	48.9	288	10.50	1.08 U	0.06	1.86	0.00050	68.5
322-45	RM-7-25	24.9	17.5	83.7	212	14.32	1.08 U	0.05	1.80	0.00492	94.2
322-46	RM-7-26	48.8	36.1	162	247	19.09	1.08 U	0.93	3.20	0.02969	127
322-47	RM-8-13	102	86.3	134	135	18.13	1.08 U	0.80	1.30	0.40913	55.5
322-48	RM-8-14	36.1	49.8	25.7	204	21.95	1.08 U	0.06	1.12	0.00112	59.5
322-49	RM-8-15	116	128	231	305	20.04	1.08 U	0.18	2.02	0.06230	82.5
322-50	RM-8-16	170	151	274	311	20.52	1.08 U	0.68	2.60	0.02581	120
322-51	RM-8-17	152	140	221	309	18.61	1.08 U	0.29	1.92	0.00591	105
322-52	RM-8-18	19.9	19.9	24.6	106	20.04	1.08 U	0.04	0.76	0.00313	44.8
322-53	RM-8-19	42.5	34.8	53.2	219	17.66	1.08 U	0.15	1.47	0.00413	73.8
322-54	RM-8-20	120	143	271	403	19.09	1.08 U	0.08	2.07	0.00078	105
322-55	RM-8-21	261	228	368	484	19.09	1.08 U	1.82	2.95	0.34150	162

U = Analyte not detected above detection limits.

1/8/92

WES RICHMOND (CF #322)
WATER METAL RESULTS
 (concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As AA	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
322-56	RM-8-22	25.2	27.4	17.3	193	15.27	1.06 U	0.03	1.09	0.00089	65.0
322-57	RM-8-23	29.4	25.1	98.4	224	23.86	1.06 U	0.08	1.75	0.08690	116
322-58	RM-8-24	29.2	10.8	121	150	21.95	1.06 U	0.40	1.39	0.01781	87.9
322-59	RM-9-10	4.57	185	152	1 U	20.52	1.83	0.46	0.24	0.01107	1 U
322-60	RM-9-11	1.88	98.7	1.80	3.03	21.95	1.22	0.12	<0.01	0.00558	1 U
322-61	RM-9-12	1.57	74.2	2.57	2.00	26.72	1.08 U	0.07	0.25	0.00846	1 U
322-62	RM-9-13	2.05	77.6	1.15	6.22	22.43	1.06 U	0.04	0.02	0.01012	1 U
322-63	RM-9-14	3.34	66.1	2.78	3.11	21.95	1.06 U	0.03	0.01	0.00552	1 U
322-64	RM-9-15	3.28	43.5	10.1	7.33	25.29	1.22	0.05	0.02	0.00729	3.06
322-65 Rep 1	RM-9-16	17.5	42.7	26.2	16.1	24.81	1.08 U	0.19	0.30	0.04217	8.07
322-65 Rep 2	RM-9-16	17.5	45.5	25.9	17.8	23.86	1.08 U	0.09	0.02	0.04484	7.93
322-66	RM-9-17	7.08	30.8	25.8	1 U	22.90	1.22	0.50	<0.01	0.05219	11.5
322-67	RM-9-18	13.9	31.4	32.0	33.5	21.00	1.06 U	0.11	0.11	0.00394	14.3
322-68	RM-9-19	25.4	29.2	34.4	7.21	12.41	1.06 U	0.44	0.08	0.13761	12.8
322-69	RM-9-20	7.21	14.0	14.9	19.9	15.75	1.06 U	0.04	0.78	0.01678	7.06
322-70	RM-9-21	4.62	10.7	13.2	13.0	12.88	1.08 U	0.05	0.10	0.00195	7.01
322-71	RM-8-25	19.1	16.7	45.8	142	17.18	1.08 U	0.05	0.86	0.01966	54.1
322-72	RM-8-26	51.8	58.9	121	154	12.41	1.06 U	0.13	1.06	0.00698	53.2
322-73	RM-9-22	10.1	17.5	19.7	17.1	13.36	1.06 U	0.05	0.18	0.00490	7.63
322-74	RM-9-23	13.1	24.0	28.0	36.5	115.27	1.06 U	0.06	0.21	0.00286	13.6
322-75	RM-9-24	7.29	13.8	20.1	34.0	12.41	1.06 U	0.07	0.43	0.00669	12.5
322-76	RM-9-25	6.32	11.6	18.2	103	10.50	1.06 U	0.05	0.31	0.00297	8.33
322-77	RM-9-26	9.17	15.5	22.1	27.8	11.45	1.06 U	0.07	0.18	0.00544	9.61

U = Analyte not detected above the detection limits

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WES RICHMOND (CF #322)
WATER METAL RESULTS
(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As AA	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
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STANDARD REFERENCE MATERIAL

1643b Rep 1		18.6	49.0	22.8	73.4	NA	NA	10.7	20.8	NA	20.2
1643b Rep 2		20.0	54.8	25.9	81.3	NA	NA	11.1	20.9	NA	21.5
	certified	0.36	1.07	3.58	1.34	NA	NA	NC	0.015	NA	0.106
	value	±0.04	±0.06	±0.3	±0.2	NA	NA	NC	±0.002	NA	±0.011
1643c		NA	NA	NA	NA	NA	13.4	NA	NA	NA	NA
	certified	NA	NA	NA	NA	NA	12.7	NA	NA	NA	NA
	value	NA	NA	NA	NA	NA	±0.7	NA	NA	NA	NA
SLRS Rep 1		1 U	0.06	3.45	1 U	NA	NA	0.03	0.04	NA	1 U
SLRS Rep 2		1 U	0.05	3.56	1 U	NA	NA	0.07	0.05	NA	1 U
	certified	18.6	49	21.9	68	NA	NA	9.8	20	NA	23.7
	value	±0.4	±3	±0.4	±2	NA	NA	±0.8	±1	NA	±0.7
1641b Rep 1		NA	NA	NA	NA	NA	NA	NA	NA	1.46	NA
	certified	NA	NA	NA	NA	NA	NA	NA	NA	1.52	NA
	value	NA	NA	NA	NA	NA	NA	NA	NA	±0.08	NA

U = Analyte not detected above the detection limits.
NA = Not applicable.
NC = Not certified.

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WES RICHMOND (CF #322)
WATER METAL RESULTS
(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	AA	AA	ICP-MS	ICP-MS	CVA	ICP-MS

MATRIX SPIKE RESULTS

Amount Spiked	20	20	20	20	20	21.95	42.86	100	1	50	5
322-50 + Spike	180	175	262	277	277	42.95	40.85	1.03	3.29	0.0672	117
322-50	170	151	274	311	311	20.04	1.06 U	0.68	2.6	0.0258	120
Amount Recovered	10	24	-12	-34	-34	22.91	40.85	0.35	0.69	0.0414	-3
Percent Recovery	50%	120%	-60%	-170%	-170%	104%	95%	0%	69%	83%	-60%
Amount Spiked	20	20	20	20	20	21.95	42.86	100	1	50	5
322-68 + Spike	43.9	29.2	64.6	32.0	32.0	37.7	45.12	0.88	1.92	0.1033	16.1
322-68	25.4	31.4	34.4	7.21	7.21	12.41	1.06 U	0.44	0.08	0.0522	12.8
Amount Recovered	18.5	-2.2	30.2	24.79	24.79	25.29	45.12	0.42	1.84	0.0511	3.3
Percent Recovery	93%	-11%	151%	124%	124%	115%	105%	0%	184%	102%	66%

U = Analyte not detected above the detection limits.

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WES RICHMOND (CF #322)
WATER METAL RESULTS
 (concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	AA	AA	ICP-MS	ICP-MS	CVA	ICP-MS
1% HNO3 Rep 1		0.32	0.01 U	0.01 U	0.33	NA	NA	0.01 U	0.01 U	NA	0.01 U
1% HNO3 Rep 2		0.1 U	0.5 U	0.1 U	0.1 U	NA	NA	0.05	0.06	NA	0.1 U
322-1	RM-7-1	143	613	4.39	29.1	17.18	0.71 U	0.05	0.18	0.0298	0.61
322-1	RM-7-1	155	566	4.11	27.5	NA	0.71 U	0.05	0.12	NA	0.32
322-2	RM-7-2	60.5	365	9.02	21.9	24.34	0.71 U	0.04	0.00	0.01992	0.57
322-3	RM-7-3	46.1	328	12.2	25.2	23.38	0.71 U	0.02	0.03	0.01625	1.53
322-4	RM-7-4	26.2	193	3.20	23.4	20.52	0.71 U	0.00	0.02	0.01904	0.39
322-5	RM-7-5	17.5	141	2.21	19.5	21.48	0.71 U	0.01	0.01	0.01869	0.15
322-6	RM-7-6	9.30	111	6.12	23.4	21.48	0.71 U	0.02	0.01	0.02768	0.05
322-7	RM-7-7	9.84	101	21.7	17.8	17.68	0.71 U	0.01 U	0.01 U	0.0064	1.80
322-8	MR-7-8	5.68	79.0	5.89	16.4	20.04	0.71 U	0.01 U	0.01 U	0.00573	0.17
322-9	RM-7-9	1.72	42.3	4.85	9.84	23.38	0.71 U	1.0 U	0.01 U	0.00643	0.05
322-10	RM-7-10	4.50	43.1	5.32	21.5	23.38	0.71 U	0.00	0.01	0.01091	0.49
322-11	RM-7-11	3.33	23.6	9.98	23.2	18.61	0.71 U	0.02	0.13	0.03243	1.17
322-12	RM-7-12	2.74	19.1	10.2	20.0	18.61	0.71 U	0.04	0.06	0.03892	2.35
322-13 Rep 1	RM-7-13	9.41	18.9	18.4	37.1	23.38	0.71 U	0.04	0.18	0.05671	9.00
322-13 Rep 2	RM-7-13	7.84	15.6	14.5	408	NA	0.71 U	0.16	0.24	NA	7.43
322-14 Rep 1	RM-8-1	72.1	800	8.02	173	34.36	0.71 U	0.03	0.05	0.0182	0.81
322-14 Rep 2	RM-8-1	81.0	795	4.89	175	NA	0.71 U	0.16	0.29	NA	0.45
322-15 Rep 1	RM-8-2	16.6	383	4.53	47.7	38.17	0.71 U	0.00	0.13	0.01155	0.47
322-15 Rep 2	RM-8-2	17.8	353	2.25	45.5	NA	0.71 U	0.01 U	0.14	NA	0.1 U
322-16	RM-8-3	8.57	85.8	3.01	36.5	36.27	0.71 U	0.05	0.07	0.02481	0.26
322-17	RM-8-4	2.69	65.9	7.49	24.5	42.47	0.71 U	0.06	0.10	0.01984	0.09
322-18	RM-8-5	1.45	38.1	8.83	19.3	37.70	0.71 U	0.03	0.08	0.00892	0.07
322-19	RM-8-6	1.54	35.1	7.80	15.8	28.15	0.71 U	0.16	0.08	0.01163	0.31
322-20	RM-8-20	1.61	29.2	7.49	15.0	27.68	0.71 U	0.03	0.02	0.00597	0.12

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WES RICHMOND (CF #322)
WATER METAL RESULTS
 (concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As AA	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVA	Pb ICP-MS
322-21 Rep 1	RM-8-8	2.54	24.8	5.11	16.8	28.63	0.71 U	0.01 U	0.02	0.00747	0.13
322-21 Rep 1a	RM-8-8	2.02	20.9	0.1 U	286	NA	NA	0.01	0.08	NA	0.1 U
322-21 Rep 2	RM-8-8	2.56	22.7	4.63	274	28.15	0.71 U	0.13	0.01 U	0.00771	0.23
322-21 Rep 2a	RM-8-8	1.72	19.9	0.1 U	9.36	NA	NA	0.50	0.04	NA	0.1 U
322-22	RM-8-9	2.59	20.9	8.7	15.6	29.58	0.71 U	0.02	0.04	0.01493	0.74
322-23	RM-8-10	4.46	18.2	11.6	20.6	24.81	0.71 U	0.06	0.06	0.0288	2.17
322-24	RM-8-11	7.58	16.4	14.9	223	22.43	0.71 U	0.06	0.23	0.05327	8.34
322-25	RM-8-12	15.2	26.2	28.3	49.6	23.38	0.71 U	0.01	0.31	0.00787	14.3
322-26	RM-9-1	62.2	114	25.9	124	12.88	0.71 U	0.23	1.09	0.02226	2.44
322-27	RM-9-2	17.3	71.6	7.43	21.5	15.27	0.71 U	0.03	0.23	0.00836	0.95
322-28	RM-9-3	2.45	52.4	6.34	17.2	13.36	0.71 U	0.03	0.25	0.01074	0.50
322-29	RM-9-4	2.05	48.2	5.34	12.4	12.41	0.71 U	0.01	0.14	0.00885	0.37
322-30	RM-9-5	1.24	39.4	4.13	14.4	12.41	0.71 U	0.02	0.08	0.01155	0.26
322-31	RM-9-6	1.54	76.1	0.94	11.5	1.65 U	0.71 U	0.03	0.11	0.00202	0.09
322-32	RM-9-7	3.19	48.8	0.24	15.0	11.45	0.71 U	0.02	0.07	0.00631	0.38
322-33	RM-9-8	2.52	56.8	5.94	12.9	9.54	0.71 U	0.07	0.04	0.00777	0.94
322-34 Rep 1	RM-9-9	1.05	38.0	0.28	13.8	14.79	0.71 U	0.03	0.07	0.00745	0.20
322-34 Rep 2	RM-9-9	1.19	40.9	0.41	10.8	15.27	0.71 U	0.08	0.03	0.00939	0.22

U = Indicates analyte not detected above the detection limits.

NA = Indicates not applicable

() = Indicates value is suspect; values obtained for duplicate runs and different isotopes had significant variation.

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WES RICHMOND (CF #322)
WATER METAL RESULTS
(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As AA	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
STANDARD REFERENCE MATERIAL											
SLRS Rep 1		0.60	0.94	3.23	2.34	NA	NA	0.01 U	0.01 U	NA	0.03
SLRS Rep 2	certified values	0.1 U 0.36 ±0.04	1.79 1.07 ±0.08	3.19 3.58 ±0.3	2.95 1.34 ±0.2	NA NA NA	NA NA NA	0.02 NC NC	0.04 0.015 ±0.002	NA NA NA	0.24 0.106 ±0.011
1643b Rep 1		19.8	49.4	22.0	119	NA	NA	11.1	20.7	NA	20.8
1643b Rep 2	certified values	19.0 18.6 ±0.4	42.8 49 ±3	18.7 21.9 ±0.4	102 66 ±2	NA NA NA	NA NA NA	10.9 9.8 ±0.8	18.4 20 ±1	NA NA NA	23.1 23.7 ±0.7
1643c Rep 1		NA	NA	NA	NA	81.47	15.58	NA	NA	NA	NA
1643c Rep 2	certified values	NA NA NA	NA NA NA	NA NA NA	NA NA NA	81.47 8.10 ±1.2	NA 12.70 ±0.7	NA NA NA	NA NA NA	NA NA NA	NA NA NA
1641b Rep 1		NA	NA	NA	NA	NA	NA	NA	NA	1.40	NA
	certified values	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	1.52 ±0.05	NA NA

U = Indicates analyte not detected above the detection limits.
NA = Indicates not applicable.
NC = Indicates not certified.

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WES RICHMOND (CF #322)
WATER METAL RESULTS
(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	AA	AA	ICP-MS	ICP-MS	CVAA	ICP-MS

MATRIX SPIKE RESULTS

Amount Spiked		20	20	20	20	21.95	21.95	100	1	100	5
322-20+spike		18.1	45.2	22.4	34.3	45.81	21.95	78.0	1.06	99.48	4.87
322-20	RM-8-20	1.61	29.2	7.49	15.0	27.68	0.71 U	0.03	0.02	5.97	0.12
Amount Recovered		16.503	15.98	14.948	19.25	18.13	21.95	77.981	1.0454	93.51	4.755
Percent Recovery		83%	80%	75%	96%	83%	100%	78%	105%	94%	95%
Amount Spiked		NA	NA	NA	NA	NA	NA	1	NA	NA	NA
322-20+spike 100x		NA	NA	NA	NA	NA	NA	0.88	NA	NA	NA
322-20	RM-8-20	NA	NA	NA	NA	NA	NA	0.03	NA	NA	NA
Amount Recovered		NA	NA	NA	NA	NA	NA	0.8479	NA	NA	NA
Percent Recovery		NA	NA	NA	NA	NA	NA	85%	NA	NA	NA
Amount Spiked		20	20	20	20	21.95	21.95	100	1	100	5
322-33+spike		24.0	75.8	25.6	25.7	31.97	20.53	63.0	0.89	105.76	4.91
322-33	RM-9-8	2.52	56.8	5.94	12.9	9.54	0.71 U	0.07	0.04	7.77	0.94
Amount Recovered		21.487	19.065	19.6887	12.861	22.43	20.53	62.948	0.8522	97.99	3.967
Percent Recovery		107%	95%	98%	64%	102%	94%	63%	85%	98%	79%
Amount Spiked		NA	NA	NA	NA	NA	NA	1	NA	NA	NA
322-33+spike 100x		NA	NA	NA	NA	NA	NA	0.81	NA	NA	NA
322-33	RM-9-8	NA	NA	NA	NA	NA	NA	0.07	NA	NA	NA
Amount Recovered		NA	NA	NA	NA	NA	NA	0.74	NA	NA	NA
Percent Recovery		NA	NA	NA	NA	NA	NA	74%	NA	NA	NA

NA = Indicates not applicable.

339 METALS DATA

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WES RICHMOND (CF #339)
 WATER METAL RESULTS
 (concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As ICP-MS	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
339-12	RID-1-MET-U	24.1	48.6	82.3	149	6.8	1.12 U	1.02	0.67	0.0009 U	35.8
339-13	RID-1-MET-F	0.3	1.4	3.1	10.7	2.8	1.12 U	1.04	0.06	0.0009 U	0.39
339-14	RID-1-MET-RO	0.2	0.5	1.4	1.6	0.4	1.12 U	1.09	0.05	ND	0.14
339-15	RID-2-MET-U	28.1	61.4	94.4	164	10.7	1.12 U	1.23	1.38	0.0009 U	44.6
339-16 REP 1	RID-2-MET-F	0.6	1.7	2.5	64.7	4.7	1.12 U	1.07	0.07	0.0009 U	0.38
339-16 REP 2	RID-2-MET-F	0.5	1.7	2.7	13	4.3	1.12 U	1.07	0.09	0.0009 U	0.25
339-17	RID-2-MET-RO	0.2	15.4	1.5	1.5	0.4	1.12 U	1.1	0.01	0.0009 U	2.17
339-18	RID-3-METU-1	20.9	45.5	91.5	151	7.4	1.12 U	1.17	1.92	ND	42.5
339-19	RID-3-METU-2	23.5	57.8	92.3	157	8.7	1.12 U	1.21	1.98	0.0032	47.2
339-20	RID-3-METF-1	0.3	1.2	4.2	12.5	4.8	1.12 U	0.99	0.13	0.0009 U	0.5
339-21	RID-3-METF-2	0.3	16	2.6	10.3	1.5	1.12 U	1.1	0.09	0.0009 U	0.35
339-22	RID-3-MET-RO	0.2	1.4	24.5	4.4	0.4	1.12 U	1.08	0.04	0.0009 U	1.61

U = Indicates below detection limit.

ND = Indicates not detected.

339 METALS DATA

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WES RICHMOND (CF #339) WATER METAL RESULTS (concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	AA	ICP-MS	ICP-MS	CVA	ICP-MS

STANDARD REFERENCE MATERIAL

1643b		18.9	42.6	20.1	56.7	47	NA	9.33	19.4	NA	23.5
(SRM 3)	certified values	18.6	49	21.9	66	NC	NA	9.8	20	NA	23.7
		±0.4	±3	±0.4	±2	NC	NA	±0.8	±1	NA	±0.7
1643c		NA	NA	NA	NA	NA	14.2	NA	NA	NA	NA
	certified values	NA	NA	NA	NA	NA	12.7	NA	NA	NA	NA
		NA	NA	NA	NA	NA	±0.7	NA	NA	NA	NA
1641b		NA	NA	NA	NA	NA	NA	NA	NA	1.43	NA
	certified values	NA	NA	NA	NA	NA	NA	NA	NA	1.52	NA
		NA	NA	NA	NA	NA	NA	NA	NA	±0.04	NA

MATRIX SPIKE RESULTS

Amount Spiked	20	20	20	20	20	20	20	100	1	0.0333	5
339-15 + Spike	55.6	96.1	116	187	29.3	29.3	41.32	54.5	2.41	0.0313	45
339-15	28.1	61.4	94.4	164	10.7	10.7	1.12 U	1.23	1.38	0.0009 U	44.6
Amount Recovered	27.5	34.7	21.6	23	18.6	18.6	41.32	53.27	1.03	0.0313	0.4
Percent Recovered	138%	174%	108%	115%	93%	93%	96%	53%	103%	94%	8%

NA = Indicates not applicable.

NC = Indicates not certified.

U = Indicates below detection limit.

339 METALS DATA

1/8/92

WES RICHMOND (CF #339)
 WATER METAL RESULTS
 (concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As ICP-MS	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
339-12	RID-1-MET-U	24.1	48.6	82.3	149	6.8	1.12 U	1.02	0.67	0.0009 U	35.8
339-13	RID-1-MET-F	0.3	1.4	3.1	10.7	2.8	1.12 U	1.04	0.06	0.0009 U	0.39
339-14	RID-1-MET-RO	0.2	0.5	1.4	1.6	0.4	1.12 U	1.09	0.05	ND	0.14
339-15	RID-2-MET-U	28.1	61.4	94.4	164	10.7	1.12 U	1.23	1.38	0.0009 U	44.6
339-16 REP 1	RID-2-MET-F	0.6	1.7	2.5	64.7	4.7	1.12 U	1.07	0.07	0.0009 U	0.38
339-16 REP 2	RID-2-MET-F	0.5	1.7	2.7	13	4.3	1.12 U	1.07	0.09	0.0009 U	0.25
339-17	RID-2-MET-RO	0.2	15.4	1.5	1.5	0.4	1.12 U	1.1	0.01	0.0009 U	2.17
339-18	RID-3-METU-1	20.9	45.5	91.5	151	7.4	1.12 U	1.17	1.92	ND	42.5
339-19	RID-3-METU-2	23.5	57.8	92.3	157	8.7	1.12 U	1.21	1.98	0.0032	47.2
339-20	RID-3-METF-1	0.3	1.2	4.2	12.5	4.8	1.12 U	0.99	0.13	0.0009 U	0.5
339-21	RID-3-METF-2	0.3	1.6	2.6	10.3	1.5	1.12 U	1.1	0.09	0.0009 U	0.35
339-22	RID-3-MET-RO	0.2	1.4	24.5	4.4	0.4	1.12 U	1.08	0.04	0.0009 U	1.61

U = Indicates below detection limit.

ND = Indicates not detected.

339 METALS DATA

1/8/92

WES RICHMOND (CF #339) WATER METAL RESULTS (concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	AA	ICP-MS	ICP-MS	CVAA	ICP-MS

STANDARD REFERENCE MATERIAL

1643b (SRM 3)	certified values	18.9 18.6 ±0.4	42.6 49 ±3	20.1 21.9 ±0.4	56.7 66 ±2	47 NC NC	NA NA NA	9.33 9.8 ±0.8	19.4 20 ±1	NA NA NA	23.5 23.7 ±0.7
1643c	certified values	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	14.2 12.7 ±0.7	NA NA NA	NA NA NA	NA NA NA	NA NA NA
1641b	certified values	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	1.43 1.52 ±0.04	NA NA NA

MATRIX SPIKE RESULTS

Amount Spiked	20	20	20	20	20	20	42.86	100	1	0.0333	5
339-15 + Spike	55.6	96.1	116	187	29.3	29.3	41.32	54.5	2.41	0.0313	45
339-15	28.1	61.4	94.4	164	10.7	10.7	1.12 U	1.23	1.38	0.0009 U	44.6
Amount Recovered	27.5	34.7	21.6	23	18.6	18.6	41.32	53.27	1.03	0.0313	0.4
Percent Recovered	138%	174%	108%	115%	93%	93%	96%	53%	103%	94%	8%

NA = Indicates not applicable.
NC = Indicates not certified.
U = Indicates below detection limit.

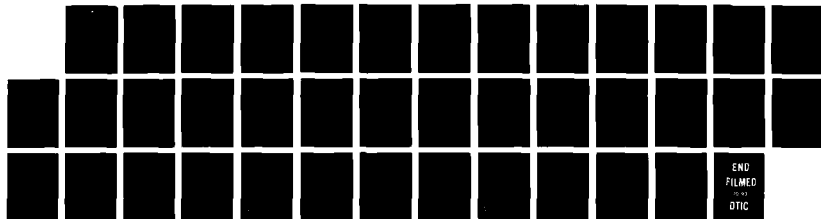
AD-A269 951

EVALUATION OF UPLAND DISPOSAL OF RICHMOND HARBOR
CALIFORNIA SEDIMENT FROM SANTA FE CHANNEL (U) ARMY
ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS
ENVIRONMENTAL LAB C R LEE ET AL. JUL 93

373

UNCLASSIFIED

NL



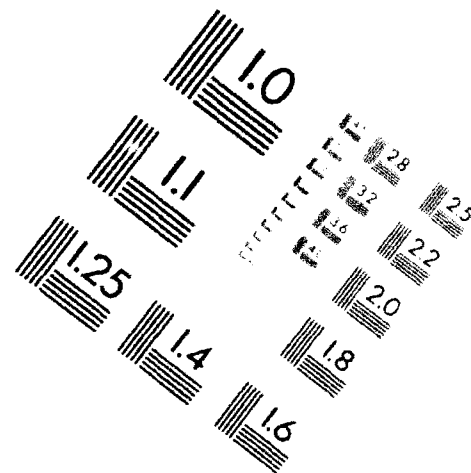
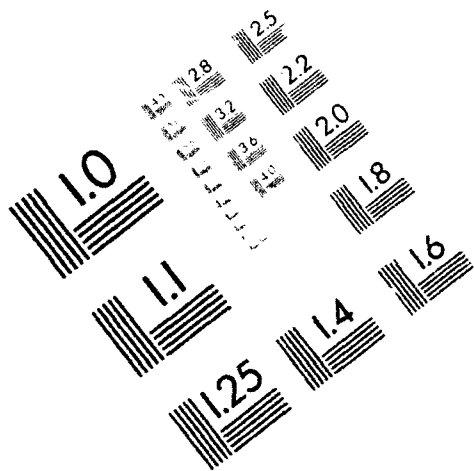


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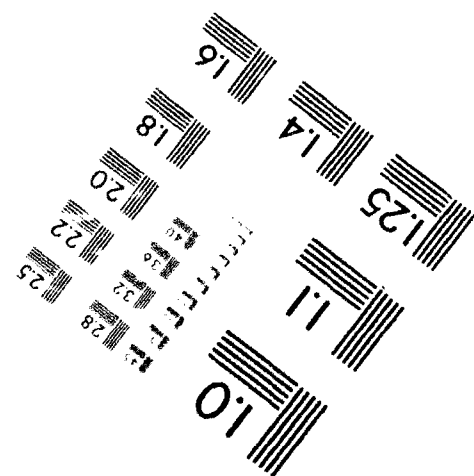
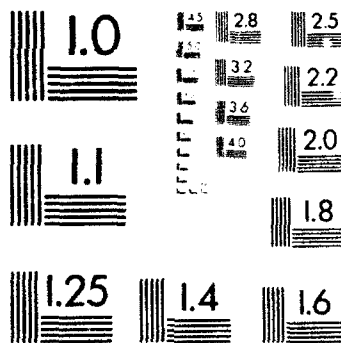
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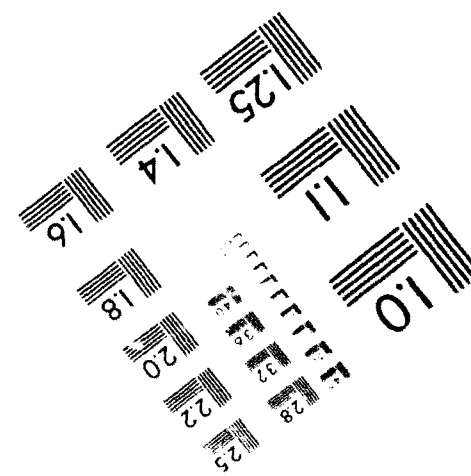
Centimeter



Inches



MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.



08/24/91

WES RICHMOND (CF#339)

PAH CONCENTRATIONS

IN WATER DATA

(concentrations in ug/L)

Battelle ID	Sponsor ID.	Naph- thalene	Acenaph- thylene	Acenaph- thene	Flourene	Phenan- threne	Anthra- cene	Flouren- thene	Pyrene	Benzo(a)- Anthracene
339-2	RID-1-PAHU	46.4 B	10.0 U	10.0 U	12.4	34.0	10.0 U	29.2	53.6	11.3
339-3	RID-1-RO	11.9 B	11.8 U	11.8 U	11.8 U	11.8 U	11.8 U	11.8 U	11.8 U	11.8 U
339-4	RID-2-PAHF	45.5 B	10.0 U	10.0 U	10.0 U	26.9	10.0 U	12.6	20.6	10.0 U
339-5	RID-2-PAHU	46.8 B	10.0 U	10.0 U	10.0 U	29.3	10.8	31.6	64.8	14.8
339-6	RID-2-RO	19.9 B	11.8 U	11.8 U	11.8 U	12.8	11.8 U	11.8 U	11.8 U	11.8 U
339-7	RID-3-PAHF-1	57.0 B	10.0 U	10.0 U	11.2	33.8	10.0 U	10.0 U	16.2	10.0 U
339-8	RID-3-PAHF-2	52.5 B	10.0 U	10.0 U	10.4	27.2	10.0 U	10.0 U	14.6	10.0 U
339-9	RID-3-PAHU-1	65.8 B	28.6 U	28.6 U	28.6 U	37.1	28.6 U	37.3	63.9	28.6 U
339-10	RID-3-PAHU-2	56.3 B	10.0 U	10.2	10.7	30.5	10.0 U	27.2	52.7	12.7
339-11	RID-3-RO	21.0 B	13.2 U	13.2 U	13.2 U	13.2 U	13.2 U	13.2 U	13.2 U	13.2 U
Lab Method Blank		33.6	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U

U = Indicates analyte not detected above the detection limit.

B = Used when the analyte is found in the associated blank as well as in the sample.

08/24/91
WES RICHMOND (CF#339)
PAH CONCENTRATIONS
IN WATER DATA

(concentrations in ug/L)												% Surrogate Recovery			
Battelle ID	Sponsor ID.	Benzo(b)-Flouranthene					Indeno-(1,2,3-cd) Pyrene		Dibenz(a,h)-Anthracene		Benzo(ghi)-Perylene		D10 Anthracene	D10 Pyrene	
		Chrysene	Pyrene	Pyrene	Pyrene	Pyrene	Pyrene	Pyrene	Pyrene	Pyrene	Pyrene				
339-2	RID-1-PAHU	16.3	57.2	26.1	18.0	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	114%	110%	108%
339-3	RID-1-RO	11.8 U	23.5 U	11.8 U	11.8 U	11.8 U	11.8 U	11.8 U	11.8 U	11.8 U	11.8 U	11.8 U	81%	78%	79%
339-4	RID-2-PAHF	10.0 U	20.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	104%	104%	107%
339-5	RID-2-PAHU	26.3	76.4	32.9	20.9	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	100%	102%	97%
339-6	RID-2-RO	11.8 U	23.5 U	11.8 U	11.8 U	11.8 U	11.8 U	11.8 U	11.8 U	11.8 U	11.8 U	11.8 U	102%	106%	110%
339-7	RID-3-PAHF-1	10.0 U	20.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	111%	118%	106%
339-8	RID-3-PAHF-2	10.0 U	20.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	97%	97%	93%
339-9	RID-3-PAHU-1	28.6 U	74.6	28.6	28.6	23.5 U	23.5 U	23.5 U	23.5 U	23.5 U	23.5 U	23.5 U	82%	74%	78%
339-10	RID-3-PAHU-2	19.2	64.9	25.5	16.9	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	98%	100%	96%
339-11	RID-3-RO	13.2 U	26.3 U	13.2 U	13.2 U	13.2 U	13.2 U	13.2 U	13.2 U	13.2 U	13.2 U	13.2 U	99%	97%	92%
Lab Method Blank		10.0 U	20.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	106%	108%	105%

U = Indicates analyte not detected above the detection limit.
B = Used when the analyte is found in the associated blank as well as in the sample.

8/24/91
 WES RICHMOND (CF #339)
PESTICIDE CONCENTRATIONS
IN WATER SAMPLES
 (concentrations in ug/L)

MSL Code	Sponsor Code	Lab ID	Alpha- BHC	Beta- BHC	Delta- BHC	Gamma- BHC	Hepta- chlor	Aldrin	Hepta- chlor Epoxide	Endo sulfen I	Diel- drin	4,4'- DDE	Endrin
339-2	RID-1-PHU	249638	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
339-3	RID-1-RO	249639	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
339-3	RID-2-PAHF	249640	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
339-4	RID-2-PAHU	249641	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
339-5	RID-2-RO	249642	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
339-6	RID-3-PAHF-1	249643	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
339-7	RID-3-PAHF-2	249644	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
339-8	RID-3-PAHU-1	249645	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.1
339-9	RID-3-PAHU-2	249646	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
339-10	RID-3-RO	249647	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
P. Blank			0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U

U = Indicates analyte not detected above the detection limit.

8/24/91

WES RICHMOND (CF #339)

PESTICIDE CONCENTRATIONS

IN WATER SAMPLES

(concentrations in ug/L)

MSL Code	Sponsor Code	Lab ID	Endo- Sulfan II	4,4'- DDD	Endo- sulfan Sulfate	4,4'- DDT	Methoxy- chlor	Endrin Ketone	Gamma- Chlordane	Alpha- Chlordane	Toxa- phene	Surrogate % Dibutyl- chloroendate
339-2	RID-1-PHU	249638	0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.06 U	62%
339-3	RID-1-RO	249639	0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.06 U	88%
339-3	RID-2-PAHF	249640	0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.06 U	59%
339-4	RID-2-PAHU	249641	0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.06 U	76%
339-5	RID-2-RO	249642	0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.06 U	70%
339-6	RID-3-PAHF-1	249643	0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.06 U	78%
339-7	RID-3-PAHF-2	249644	0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.06 U	108%
339-8	RID-3-PAHU-1	249645	0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.06 U	63%
339-9	RID-3-PAHU-2	249646	0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.06 U	50%
339-10	RID-3-RO	249647	0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.06 U	83%
P. Blank			0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.06 U	71%

U = Indicates analyte not detected above the detection limit.

P = Used for a pesticide/Aroclor target analyte when there is greater than 25% difference for detected concentrations between the two GC columns.
The lower of the two values is reported.

7/22/91

WES RICHMOND (CF #339)
**ORGANOTIN ANALYSIS
 OF WATER SAMPLES**

MSL Code	Sponsor Code	(concentrations in ng/L)				
		Tripentyl % Surrogate	Tetra Tin	Tributyl Tin	Dibutyl Tin	Monobutyl Tin
339-1	RID-1-PAHF	112.36	1.8 U	2.1 U	1.9 U	8.1 B
339-2	RID-1-PAHU	83.22	3.7	9.5	12.7 B	14.4 B
339-3	RID-1-RO	120.27	3.3	2 U	4.5 B	8.4 B
339-4	RID-2-PAHF	48.97	1.8 U	2.1 U	1.8 U	4.1 B
339-5	RID-2-PAHU	98.05	1.6 U	9.1	15.1 B	17.6 B
339-6	RID-2-RO	106.53	1.5 U	1.7 U	3 B	6.2 B
339-7	RID-3-PAHF-1	131.12	1.6 U	1.9 U	1.6 U	11.1 B
339-8	RID-3-PAHF-2	124.77	1.4 U	1.6 U	1.4 U	14.5 B
339-9	RID-3-PAHU-1	96.40	1.4 U	10.1	12.4 B	13.0 B
339-10	RID-3-PAHU-2	100.98	1.3 U	10.1	12.2 B	17.7 B
339-11	RID-3-RO	115.17	1.6 U	1.8 U	1.6 U	15.8 B

U = Indicates analyte not detected above detection limits.

B indicates analyte detected in method blank associated with sample

METHOD BLANK RESULTS

339-BLANK-1	147.33	1.5 U	1.8 U	1.7	9.5
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BLANK AND MATRIX SPIKE RECOVERIES

339-4-SPIKE	127.75	31.3	93.8	78.3	83.2
% Recovery		16%	47%	39%	41%
339-10-SPIKE	107.32	100.5	152.1	1123.2	77.9
% Recovery		50%	71%	55%	30%

8/24/91

WES RICHMOND (CF #339)

PESTICIDE CONCENTRATIONS IN WATER SAMPLES

(concentrations in ug/L)

 Surrogate %
Dibutyl-
chlorobenzene

Hepta-		4,4'-	
Lindane	chlordane	Aldrin	Endrin

MATRIX SPIKE RECOVERIES

 339-MS RID-3-PAHU-2
Spike Added
Spike Recovered
Percent Recovery

1.43	1.43	1.43	1.43
0.86	0.87	0.79	1.21
60%	61%	55%	78%
			90%

88%

 339-MSD RID-3-PAHU-2
Spike Added
Spike Recovered
Percent Recovery

1.43	1.43	1.43	1.43
0.89	0.90	0.80	1.20
62%	63%	56%	77%
			96%

66%

08/24/91
WES RICHMOND (CF#339)
PAH CONCENTRATIONS
IN WATER DATA
(concentrations in ug/L)

MATRIX SPIKE RECOVERIES

Naphthalene	Flourene	Anthracene	Flouranthene	Benz[a]anthracene	Benzo[a]pyrene	Benzo[ghi]perylene	% Surrogate Recovery			
							D10 ene	Flour-D10	Anthracene	D10 Pyrene
1429	1429	1429	1429	1429	1429	1429	1429	117%	114%	114%
1676	1728	1711	1703	1855	2069	2004	2004			
113%	121%	120%	117%	130%	143%	140%				
1429	1429	1429	1429	1429	1429	1429	1429	102%	99%	100%
1515	1556	1501	1550	1653	1352	1681	1681			
101%	109%	105%	106%	116%	93%	118%				

339-9 MS RID-3-PAHU-1
Spike Added
Spike Recovered
Percent Recovery

339-9 MSD RID-3-PAHU-1
Spike Added
Spike Recovered
Percent Recovery

248WATER

WATER DATA
Project: RICHMOND HARBOR
Sponsor: BRAINONPRICE

(CF#248)

3/15/91

WATER BUTYLIN RESULTS

Sample Code	Sponsor Code	(Concentrations in ng/L; ppt)					% Surrogate Recovery
		TETRA-BUTYLIN	TRI-BUTYLIN	DI-BUTYLIN	MONO-BUTYLIN	PROPYLIN	
248-1	RANK-TBT D1-1	4.2 U	4.3 U	20.0	9.3		62%
248-2	RANK-TBT D1-2	5.0 U	6.1 U	154.7	23.5		50%
248-3	RANK-TBT D1-3	3.6 U	4.1 U	3.6	3.3 U		49%
248-4	RANK-TBT D2-1	5.8 U	6.7 U	5.5 U	5.6		42%
248-5	RANK-TBT D2-2	4.1 U	4.7 U	4.3	3.7 U		54%
248-6	RANK-TBT D2-3	5.0 U	5.8 U	4.6 U	12.9		48%
248-7	RANK-TBT D7-1	4.4 U	5.9 U	5.2	12.5		46%
248-8	RANK-TBT D7-2	5.4 U	4.4 U	12.3	26.6		49%
248-9	RANK-TBT D7-3	4.6 U	5.4 U	5.4	17.9		53%
249-10	RANK-TBT H2O BLANK	4.3 U	4.6 U	3.6 U	4.0		55%
METHOD BLANK		4.3 U	4.9 U	4.0 U	4.1 U		51%

U Indicates not detected at detection limit shown.

B Indicates analyte detected in method blank

SPIKE BLANK RESULTS

Amount Spiked: 222 NG/L
Amount Recovered: 54.9
Percent Recovery: 25%

NS Indicates "not spiked"

64.1
38%

4.3
NS

27%

PAH WATER RESULTS (CF#248)

3/22/81

Project: RICHMOND

Sponsor: BRANNOVPRICE

(Concentrations in ng/L, ppt)

Bottle Code	Sample Name	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)Anthracene	Chrysene
Lab. Method Blank		31.6 U	4.8 U	12.0 U	9.6 U	12.8 U	5.6 U	8.0 U	6.0 U	5.6 U	4.8 U
Lab. Method Blank		31.8 U	4.8 U	12.0 U	9.6 U	12.8 U	5.6 U	8.0 U	6.0 U	5.6 U	4.8 U
248-11	RANK-PAH D1-1	316.8	4.8 U	12.0 U	9.6 U	12.8 U	5.6 U	8.4	45.4	5.6 U	4.8 U
248-12	RANK-PAH D1-2	330.7	9.6 U	24.0 U	19.2 U	25.6 U	11.2 U	16.0 U	29.4	11.2 U	9.6 U
248-12	RANK-PAH D1-2 DUP	291.7	11.1 U	27.7 U	22.2 U	29.6 U	12.9 U	18.5 U	47.7	12.9 U	11.1 U
248-13	RANK-PAH D1-3	278.2	16.0 U	40.0 U	32.0 U	38.4 U	16.7 U	22.4 U	67.0	22.2 U	16.0 U
248-14	RANK-PAH D2-1	147.8	19.2 U	48.0 U	38.4 U	51.2 U	22.4 U	32.0 U	40.9	22.4 U	19.2 U
248-15	RANK-PAH D2-2	122.3	9.6 U	24.0 U	19.2 U	25.6 U	11.2 U	16.0 U	44.4	11.2 U	9.6 U
248-15	RANK-PAH D2-2 DUP	88.9	7.6 U	19.0 U	15.2 U	20.3 U	8.9 U	12.7 U	30.7	8.9 U	7.6 U
248-16	RANK-PAH D2-3	65.0	4.8 U	12.0 U	9.6 U	12.8 U	5.6 U	8.0 U	33.7	5.6 U	4.8 U
248-17	RANK-PAH D7-1	90.4	4.8 U	19.1	10.7	27.3	7.2	13.1	43.8	5.6 U	4.8 U
248-18	RANK-PAH D7-2	392.0	4.8 U	12.0 U	9.6 U	38.3	7.2	41.0	71.9	6.9	6.4
248-19	RANK-PAH D7-3	31.6 U	4.8 U	12.0 U	9.6 U	12.8 U	5.6 U	22.2	65.9	5.6 U	6.0
248-20	RANK-PAH H20 BLANK	38.1	5.1 U	12.8 U	10.2 U	13.6 U	6.0 U	8.5 U	6.4 U	6.0 U	5.1 U
248-21	RANS-PAH D1-1	37.3	4.8 U	12.0 U	9.6 U	23.1	6.9	13.8	49.3	6.4	4.8 U
248-22	RANS-PAH D1-2	51.5	4.8 U	12.0 U	9.6 U	22.3	5.6 U	15.2	57.0	5.6 U	4.8 U
248-23	RANS-PAH D1-3	39.0	4.8 U	12.0 U	9.6 U	22.6	5.9	11.3	44.5	5.6 U	4.8 U
248-24	RANS-PAH D2-1	31.6 U	4.8 U	12.0 U	9.6 U	19.6	10.3	13.6	53.2	6.1	5.4
248-25	RANS-PAH D2-2	47.5	4.8 U	12.0 U	9.6 U	29.7	11.2	24.1	83.8	12.6	11.4
248-26	RANS-PAH D2-3	39.4	4.8 U	12.0 U	9.6 U	25.3	13.7	23.2	96.1	14.6	13.6
248-27	RANS-PAH D3-1	31.6 U	4.8 U	12.0 U	9.6 U	21.5	22.2	43.6	197.5	23.5	17.8
248-28	RANS-PAH D3-2	32.6 U	4.9 U	12.4 U	9.9 U	18.4	18.0	36.3	157.3	13.0	11.8
248-29	RANS-PAH D3-3	31.6 U	4.8 U	12.0 U	9.6 U	12.8 U	14.2	38.7	97.9	13.9	8.3
248-30	RANS-PAH D4-1	31.6 U	4.8 U	12.0 U	9.6 U	12.8 U	7.9	17.7	59.6	6.6	5.9
248-31	RANS-PAH D4-2	31.6 U	4.8 U	12.0 U	9.6 U	12.8 U	5.6	16.7	42.9	5.6 U	4.8 U
248-32	RANS-PAH D4-3	37.5	4.8 U	12.0 U	9.6 U	12.8 U	5.6 U	8.0 U	26.9	5.6 U	4.8 U
248-33	RANS-PAH D5-1	31.6 U	4.8 U	12.0 U	9.6 U	12.8 U	6.2	15.4	54.2	5.6 U	5.8
248-34	RANS-PAH D5-2	32.5 U	4.9 U	12.4 U	9.9 U	13.2 U	9.4	47.0	105.7	11.6	8.2
248-35	RANS-PAH D5-3	30.6 U	4.7 U	11.6 U	9.3 U	12.4	6.0	19.3	57.9	6.5	4.9
248-36	RANS-PAH D5-1	31.6 U	4.8 U	12.0 U	9.6 U	14.0	5.6 U	15.4	47.0	6.3	6.1
248-37	RANS-PAH D6-2	31.6 U	4.8 U	12.0 U	9.6 U	21.5	14.0	42.3	112.0	14.3	7.9
248-38	RANS-PAH D6-3	31.6 U	4.8 U	12.0 U	9.6 U	14.1	10.0	21.9	81.7	8.4	6.2
248-39	RANS-PAH H20 BLANK	34.8 U	5.3 U	13.2 U	10.6 U	14.1 U	6.2 U	8.8 U	6.6 U	6.2 U	5.3 U

U indicates analyte not detected at detection limit shown.

PAH WATER RESULTS (CF#248)

Project: RICHMOND

Sponsor: BRANNOY/PRICE

Bottle Code		Sample Name	Benzo(b)- Benzo(k)- Fluoranthene	Benzo(a)- Pyrene	Indeno- (1,2,3-cd) Pyrene	Dibenz(a,h)- Anthracene	Benzo(ghi)- Perylene	Recovery D10 Fluor- ene	D10 Anth- racene	D10 Py- rene
Lab. Method Blank			6.0 U	4.8 U	7.6 U	4.4 U	3.8 U	68.8	71.1	61.8
Lab. Method Blank			6.0 U	4.8 U	7.6 U	4.4 U	3.8 U	88.3	76.3	79.1
Lab. Method Blank			6.0 U	4.8 U	7.6 U	4.4 U	3.8 U	33.6	43.1	56.3
248-11		RANK-PAH D1-1	6.0 U	4.8 U	7.6 U	4.4 U	3.8 U	64.3	79.7	76.6
248-12		RANK-PAH D1-2	12.0 U	9.6 U	15.2 U	8.8 U	7.7 U	40.6	45.8	49.0
248-12		RANK-PAH D1-2 DUP	15.7	11.1 U	17.6 U	10.2 U	8.9 U	42.9	50.5	55.7
248-13		RANK-PAH D1-3	20.2	16.0 U	31.2	14.7 U	12.8 U	62.1	69.3	55.3
248-14		RANK-PAH D2-1	24.0 U	19.2 U	30.4 U	17.6 U	15.4 U	53.8	60.5	60.5
248-15		RANK-PAH D2-2	14.9	9.6 U	15.2 U	8.8 U	7.7 U	37.8	44.0	47.7
248-15		RANK-PAH D2-2 DUP	9.5 U	7.6 U	12.1 U	7.0 U	6.1 U	28.3	30.2	35.8
248-16		RANK-PAH D2-3	11.8	4.8 U	7.6 U	4.4 U	3.8 U	45.4	56.1	54.5
248-17		RANK-PAH D7-1	24.7	6.9	7.6 U	4.4 U	3.8 U	61.8	68.5	58.4
248-18		RANK-PAH D7-2	34.4	13.8	7.6 U	4.4 U	3.8 U	64.2	68.2	61.8
248-19		RANK-PAH D7-3	29.7	9.5	7.6 U	4.4 U	3.8 U	41.1	64.8	68.5
248-20		RANK-PAH H20 BLANK	6.4 U	5.1 U	8.1 U	4.7 U	4.1 U	58.1	61.5	69.4
248-21		RANS-PAH D1-1	14.4	6.1	7.6 U	4.4 U	3.8 U	59.8	70.5	64.7
248-22		RANS-PAH D1-2	15.2	6.4	7.6 U	4.4 U	3.8 U	63.3	75.0	69.1
248-23		RANS-PAH D1-3	16.5	6.7	7.6 U	4.4 U	3.8 U	60.8	66.3	54.6
248-24		RANS-PAH D2-1	32.5	12.9	7.9	4.4 U	13.9	51.0	65.6	57.1
248-25		RANS-PAH D2-2	82.3	36.6	26.2	4.4 U	49.2	72.5	82.1	70.6
248-26		RANS-PAH D2-3	126.7	57.7	44.3	4.4 U	81.0	71.0	80.3	71.5
248-27		RANS-PAH D3-1	98.8	39.9	6.8	4.4 U	10.7	36.1	40.2	39.2
248-28		RANS-PAH D3-2	87.3	32.6	7.8 U	4.5 U	5.4	51.6	58.1	58.8
248-29		RANS-PAH D3-3	57.2	21.3	7.6 U	4.4 U	7.4	63.5	69.9	68.5
248-30		RANS-PAH D4-1	25.4	10.8	7.6 U	4.4 U	3.8 U	69.1	72.7	69.5
248-31		RANS-PAH D4-2	18.2	6.8	7.6 U	4.4 U	3.8 U	66.5	73.2	77.5
248-32		RANS-PAH D4-3	11.9	4.8 U	7.6 U	4.4 U	3.8 U	64.4	66.7	68.5
248-33		RANS-PAH D5-1	28.8	10.3	7.6 U	4.4 U	3.8 U	74.8	78.7	82.0
248-34		RANS-PAH D5-2	60.7	25.2	7.8 U	4.5 U	4.0 U	52.3	58.7	65.1
248-35		RANS-PAH D5-3	46.9	16.3	7.4 U	4.3 U	6.5	51.3	55.0	55.4
248-36		RANS-PAH D5-1	20.1	7.4	7.6 U	4.4 U	3.8 U	67.3	67.4	69.0
248-37		RANS-PAH D6-2	43.9	21.2	7.6 U	4.4 U	5.3	54.0	58.5	55.2
248-38		RANS-PAH D6-3	53.3	19.3	7.6 U	4.4 U	3.8 U	68.8	69.7	71.5
248-39		RANS-PAH H20 BLANK	6.6 U	5.3 U	8.4 U	4.8 U	4.2 U	63.6	65.0	72.1

U Indicates analyte not detected at detection

PAH WATER RESULTS (CF#248)

3/22/01

Project: RICHMOND

Sponsor: BRANNON/PRICE

(Concentrations in ng/L, ppb)

Battelle Code	Sample Name	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a) Anthracene	Chrysene
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MATRIX SPIKE RESULTS

Sample Spiked: RANK-PAH D2-1

Sample Results

Matrix Spike Results:

Percent Recovery:

Matrix Spike Duplicate Results:

Percent Recovery:

Relative Percent Difference:

Amount Spiked: 2000 ng/L

147.8

1482.1

68%

1496.4

75%

19.2 U

1422.4

71%

1483.3

73%

48.0 U

1357.1

68%

1391.5

70%

38.4 U

1456.2

73%

1476.5

74%

22.4 U

1509.4

75%

1527.4

76%

32.0 U

1890.0

94%

1922.7

96%

40.9

1857.4

76%

1853.9

76%

21.4 U

1541.5

77%

1632.2

82%

19.2 U

1417.2

71%

1417.9

71%

Sample Spiked: RANK-PAH D1-3

Sample Results

Matrix Spike Results:

Percent Recovery:

Matrix Spike Duplicate Results:

Percent Recovery:

Relative Percent Difference:

Amount Spiked: 1667 ng/L

276.2

136.6

0%

1364.6

68%

16.0 U

758.6

38%

1183.8

59%

40.0 U

805.1

40%

1213.2

61%

32.0 U

1063.4

54%

1237.4

62%

18.7 U

1449.4

72%

1324.4

66%

65.5

1778.8

86%

1462.0

73%

67.0

1505.5

72%

1308.0

65%

22.2

1616.9

80%

1488.1

74%

16.0 U

1563.1

77%

1366.3

68%

* Indicates recovery outside of the control limits : 50 - 150%.

PAH WATER RESULTS (CF#248)
 Project: RO-MOND
 Sponsor: BRANNONPRICE

Battelle Code	Sample Name	Surrogate Percent Recovery						
		Benzo(b)- Benzo(k)- Fluoranthene	Benzo(a)- Pyrene	Indeno- (1,2,3-cd) Pyrene	Dibenz(a,h)- Anthracene	Benzo(ghi)- Perylene	D10 Fluor- ene	D10 Anth- racene D10 Py- rene

MATRIX SPIKE RESULTS

Sample Spiked: RANK-PAH D2-1

Sample Results

Matrix Spike Results:

Percent Recovery:

Matrix Spike Duplicate Results:

Percent Recovery:

Relative Percent Difference:

Sample Spiked: RANK-PAH D1-3

Sample Results

Matrix Spike Results:

Percent Recovery:

Matrix Spike Duplicate Results:

Percent Recovery:

Relative Percent Difference:

* Indicates recovery outside of the control limit

24.0 U	19.2 U	30.4 U	17.6 U	15.4 U	53.8	60.5	60.5	60.5
3768.6	1827.0	976.3	1086.5	822.7	59.1	69.4	69.4	71.8
94%	81%	47%*	53%*	40%*				
3633.6	1703.2	811.2	909.8	680.0	53.6	63.8	63.8	64.9
91%	85%	41%*	45%*	34%*				
4%	5%	15%	16%	16%				

20.2	16.0 U	31.2	14.7 U	12.6 U	62.1	69.3	69.3	55.3
3333.5	1588.8	883.9	946.1	823.5	49.9	72.4	72.4	77.0
99%	79%	43%*	47%*	41%*				
3512.9	1393.8	1147.8	1244.6	1077.0	59.7	67.4	67.4	67.7
105%	70%	57%	62%	54%				
6%	13%	29%	27%	27%				

BUTYLtin RESULTS FOR RICHMOND WATERS

WES - RICHMOND (CF #257)

Sponsor: C. Price/ R. Brannon

6/12/91

MSL Code	Sponsor Code	Triphenyl % Surrogate	Tetra ng/unit	Tributyl ng/unit	Dibutyl ng/unit	Monobutyl ng/unit
257- BLK -1		86.39	1.4 U	12.0	4.5	6.4
257- 11	RANS-TBT-D1-1	95.26	1.8 U	15.7 B	38.6 B	28.3 B
257- 12	RANS-TBT-D1-2	99.07	1.4 U	13.9 B	51.9 B	17.8 B
257- 13	RANS-TBT-D1-3	103.32	1.7	24.2 B	7.0 B	11.0 B
257- 14	RANS-TBT-D2-1	96.05	1.1 U	53.9 B	58.6 B	19.3 B
257- 15	RANS-TBT-D2-2	96.89	1.2 U	32.9 B	53.4 B	36.5 B
257- 16	RANS-TBT-D2-3	105.38	1.5 U	122.0 B	48.0 B	17.2 B
257- 17	RANS-TBT-D3-1	77.78	1.5 U	73.7 B	36.9 B	11.1 B
257-BLK-2		84.61	2.0 U	11.8	12.2	7.7
257- 18	RANS-TBT-D3-2	80.28	1.8 U	57.0 B	42.8 B	16.0 B
257- 19	RANS-TBT-D3-3	66.87	2.0 U	97.2 B	27.2 B	12.1 B
257- 20	RANS-TBT-D4-1	91.64	1.8 U	40.4 B	20.3 B	9.9 B
257- 21	RANS-TBT-D4-2	83.78	2.0 U	34.0 B	23.6 B	13.4 B
257- 22	RANS-TBT-D4-3	79.79	1.4 U	83.4 B	47.9 B	19.7 B
257- 23	RANS-TBT-D5-1	88.41	2.1 U	44.9 B	29.0 B	18.1 B
257- 24	RANS-TBT-D5-2	97.82	2.0 U	21.6 B	22.1 B	16.9 B
257- 25	RANS-TBT-D5-3	82.34	1.6 U	23.0 B	16.2 B	14.7 B
257- 26	RANS-TBT-D6-1	84.77	2.3 U	16.1 B	16.2 B	17.2 B
257- 27	RANS-TBT-D6-2	N.S.	1.4 U	16.4 B	15.2 B	13.8 B
257- 28	RANS-TBT-D6-3	N.S.	1.4 U	26.9 B	18.6 B	14.2 B
257- 29	RANS-TBT-H20 BLK	N.S.	1.6 U	11.1 B	13.9 B	23.9 B

U Indicates not detected at detection limit shown

B Indicates analyte present in method blank associated with sample

MATRIX SPIKE RESULTS

257-SPK-BL-1	93.93	110.5	187.8	196.9	83.4
Percent Recovery		55%	88%	96%	16%
257-SPK-BL-2	91.60	31.2	101.9	144.2	25.7
Percent Recovery		16%	45%	66%	9%

257PEST

CLORINATED PESTICIDE RESULTS FOR RICHMOND WATERS

WES - RICHMOND (CF #257)

Sponsor: C. Price/ R. Brannon

6/12/81

MSL Code	Sponsor Rep Code	Date Ext'd	Date Anal'd	Units	Aldrin	Alpha-BHC	Beta-BHC	Delta-BHC	Chlordane	4,4'-DDD
257- 1	RANK-PEST D1-1	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.12
257- 2	RANK-PEST D1-2	12/10/90	12/20/90 & 1/28/91	µg/L	3.0 U	0.06 U	0.06 U	0.06 U	0.06 U	0.23
257- 3	RANK-PEST D1-3	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 4	RANK-PEST D2-1	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.20
257- 5	RANK-PEST D2-2	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.16
257- 6	RANK-PEST D2-3	12/10/90	12/20/90 & 1/28/91	µg/L	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U	3.0 U
257- 7	RANK-PEST D7-1	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.18
257- 8	RANK-PEST D7-2	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 9	RANK-PEST D7-3	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 10	RANK-PEST H2O BLANK	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 30	RANK-PEST D1-1	12/11/90	12/26/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.16
257- 31	RANK-PEST D1-2	12/11/90	12/26/90 & 1/28/91	µg/L	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U
257- 32	RANK-PEST D1-3	12/11/90	12/26/90 & 1/28/91	µg/L	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U
257- 33	RANK-PEST D2-1	12/11/90	12/26/90 & 1/28/91	µg/L	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U
257- 34	RANK-PEST D2-2	12/11/90	12/26/90 & 1/28/91	µg/L	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U
257- 35	RANK-PEST D2-3	12/11/90	12/26/90 & 1/28/91	µg/L	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U
257- 36	RANK-PEST D3-1	12/11/90	12/21/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	1.3
257- 37	RANK-PEST D3-2	12/11/90	12/21/90 & 1/28/91	µg/L	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U
257- 38	RANK-PEST D3-3	12/11/90	12/21/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.40
257- 39	RANK-PEST D4-1	12/11/90	12/21/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.19
257- 40	RANK-PEST D4-2	12/12/90	12/21/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.25
257- 41	RANK-PEST D4-3	12/12/90	12/21/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.48
257- 42	RANK-PEST D5-1	12/12/90	12/21/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.22
257- 43	RANK-PEST D5-2	12/12/90	12/21/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.18
257- 44	RANK-PEST D5-3	12/12/90	12/21/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.36
257- 45	RANK-PEST D5-1	12/12/90	12/21/90 & 12/28/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.27
257- 46	RANK-PEST D6-2	12/12/90	12/21/90 & 12/28/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	1.2
257- 47	RANK-PEST D6-3	12/12/90	12/21/90 & 12/28/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.17
257- 48	RANK-PEST H2O BLANK	12/12/90	12/21/90 & 12/28/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
BLANK		12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
BLANK I		12/11-12/90	12/26/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
BLANK II		12/11-12/90	12/26/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U

U indicates not detected at detection limit shown

CLORINATED PESTICIDE RESULTS FOR RICHMOND WATERS

WES - RICHMOND (CF #257)

Sponsor: C. Price/ R. Brannon

6/12/91

MSL Code	Sponsor Rep Code	Date Extd	Date Anal'd	Units	4,4'-DDE	4,4'-DDT	Dieldrin	Endo-sulfan I	Endo-sulfan II	Endosulfan Sulfate
257- 1	RANK-PEST D1-1	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 2	RANK-PEST D1-2	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 3	RANK-PEST D1-3	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 4	RANK-PEST D2-1	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 5	RANK-PEST D2-2	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 6	RANK-PEST D2-3	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 7	RANK-PEST D7-1	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 8	RANK-PEST D7-2	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 9	RANK-PEST D7-3	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 10	RANK-PEST H20 BLANK	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 30	RANK-PEST D1-1	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 31	RANK-PEST D1-2	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 32	RANK-PEST D1-3	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 33	RANK-PEST D2-1	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 34	RANK-PEST D2-2	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 35	RANK-PEST D2-3	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 36	RANK-PEST D3-1	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 37	RANK-PEST D3-2	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 38	RANK-PEST D3-3	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 39	RANK-PEST D4-1	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 40	RANK-PEST D4-2	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 41	RANK-PEST D4-3	12/12/90	12/21/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 42	RANK-PEST D5-1	12/12/90	12/21/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 43	RANK-PEST D5-2	12/12/90	12/21/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 44	RANK-PEST D5-3	12/12/90	12/21/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 45	RANK-PEST D6-1	12/12/90	12/21/90 & 12/26/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 46	RANK-PEST D6-2	12/12/90	12/21/90 & 12/26/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 47	RANK-PEST D6-3	12/12/90	12/21/90 & 12/26/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
257- 48	RANK-PEST H20 BLANK	12/12/90	12/21/90 & 12/26/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
BLANK		12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
BLANK I		12/11-12/90	12/26/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
BLANK II		12/11-12/90	12/26/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U

U Indicates not detected at detection limit shown

CLORINATED PESTICIDE RESULTS FOR RICHMOND WATERS

WES - RICHMOND (CF #257)

Sponsor: C. Price/ R. Brannon

6/12/91

MSL Code	Sponsor Rep Code	Date Ext'd	Date Anal'd	Units	Endrin	Endrin Aldehyde	Hepta-chlor	Heptachlor Epoxide	Lindane (G-BHC)	Methoxy-chlor
257- 1	RANK-PEST D1-1	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 2	RANK-PEST D1-2	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 3	RANK-PEST D1-3	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 4	RANK-PEST D2-1	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 5	RANK-PEST D2-2	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 6	RANK-PEST D2-3	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 7	RANK-PEST D7-1	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	15.0 U
257- 8	RANK-PEST D7-2	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 9	RANK-PEST D7-3	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 10	RANK-PEST H2O BLANK	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 30	RANK-PEST D1-1	12/11/90	12/26/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 31	RANK-PEST D1-2	12/11/90	12/26/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 32	RANK-PEST D1-3	12/11/90	12/26/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 33	RANK-PEST D2-1	12/11/90	12/26/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 34	RANK-PEST D2-2	12/11/90	12/26/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 35	RANK-PEST D2-3	12/11/90	12/26/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 36	RANK-PEST D3-1	12/11/90	12/26/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 37	RANK-PEST D3-2	12/11/90	12/26/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 38	RANK-PEST D3-3	12/11/90	12/26/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 39	RANK-PEST D4-1	12/12/90	12/21/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 40	RANK-PEST D4-2	12/12/90	12/21/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 41	RANK-PEST D4-3	12/12/90	12/21/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 42	RANK-PEST D5-1	12/12/90	12/21/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 43	RANK-PEST D5-2	12/12/90	12/21/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 44	RANK-PEST D5-3	12/12/90	12/21/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 45	RANK-PEST D6-1	12/12/90	12/21/90 & 12/28/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 46	RANK-PEST D6-2	12/12/90	12/21/90 & 12/28/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 47	RANK-PEST D6-3	12/12/90	12/21/90 & 12/28/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
257- 48	RANK-PEST H2O BLANK	12/12/90	12/21/90 & 12/28/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
BLANK		12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
BLANK I		12/11-12/90	12/26/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U
BLANK II		12/11-12/90	12/26/90	µg/L	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.3 U

U Indicates not detected at detection limit shown

CLORINATED PESTICIDE RESULTS FOR RICHMOND WATERS

WES - RICHMOND (CF #257)

Sponsor: C. Price/ R. Brannon

6/12/91

MSL Code	Sponsor Rep Code	Date Ext'd	Date Anal'd	Units	Endrin Kelone	Toxa- phone	DBC Surrogate % Recovery
257- 1	RANK-PEST D1-1	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.6 U	66%
257- 2	RANK-PEST D1-2	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.6 U	94%
257- 3 *	RANK-PEST D1-3	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.6 U	98%
257- 4	RANK-PEST D2-1	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.6 U	79%
257- 5	RANK-PEST D2-2	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.6 U	80%
257- 6 *	RANK-PEST D2-3	12/10/90	12/20/90 & 1/28/91	µg/L	3.0 U	30.0 U	86%
257- 7 **	RANK-PEST D7-1	12/10/90	12/20/90 & 1/28/91	µg/L	0.6 U	6.0 U	83%
257- 8	RANK-PEST D7-2	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.6 U	78%
257- 9 *	RANK-PEST D7-3	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.6 U	88%
257- 10	RANK-PEST H2O BLANK	12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.6 U	100%
257- 30	RANK-PEST D1-1	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.6 U	92%
257- 31 **	RANK-PEST D1-2	12/11/90	12/28/90 & 1/28/91	µg/L	6.0 U	60 U	54%
257- 32 **	RANK-PEST D1-3	12/11/90	12/28/90 & 1/28/91	µg/L	6.0 U	60 U	54%
257- 33 **	RANK-PEST D2-1	12/11/90	12/28/90 & 1/28/91	µg/L	6.0 U	60 U	78%
257- 34 **	RANK-PEST D2-2	12/11/90	12/28/90 & 1/28/91	µg/L	6.0 U	60 U	55%
257- 35 **	RANK-PEST D2-3	12/11/90	12/28/90 & 1/28/91	µg/L	6.0 U	60 U	54%
257- 36	RANK-PEST D3-1	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.6 U	108%
257- 37 **	RANK-PEST D3-2	12/11/90	12/28/90 & 1/28/91	µg/L	6.0 U	60 U	47%
257- 38	RANK-PEST D3-3	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.6 U	82%
257- 39	RANK-PEST D4-1	12/11/90	12/28/90 & 1/28/91	µg/L	0.06 U	0.6 U	95%
257- 40	RANK-PEST D4-2	12/12/90	12/21/90 & 1/28/91	µg/L	0.06 U	0.6 U	99%
257- 41	RANK-PEST D4-3	12/12/90	12/21/90	µg/L	0.06 U	0.6 U	108%
257- 42	RANK-PEST D5-1	12/12/90	12/21/90	µg/L	0.06 U	0.6 U	95%
257- 43	RANK-PEST D5-2	12/12/90	12/21/90	µg/L	0.06 U	0.6 U	95%
257- 44	RANK-PEST D5-3	12/12/90	12/21/90	µg/L	0.06 U	0.6 U	88%
257- 45	RANK-PEST D5-1	12/12/90	12/21/90 & 12/28/90	µg/L	0.06 U	0.6 U	99%
257- 46	RANK-PEST D6-2	12/12/90	12/21/90 & 12/28/90	µg/L	0.06 U	0.6 U	99%
257- 47	RANK-PEST D6-3	12/12/90	12/21/90 & 12/28/90	µg/L	0.06 U	0.6 U	67%
257- 48	RANK-PEST H2O BLANK	12/12/90	12/21/90 & 12/28/90	µg/L	0.06 U	0.6 U	76%
BLANK							
BLANK I		12/10/90	12/20/90 & 1/28/91	µg/L	0.06 U	0.6 U	86%
BLANK II		12/11-12/9-12/28/90		µg/L	0.06 U	0.6 U	101%
		12/11-12/9-12/28/90		µg/L	0.06 U	0.6 U	114%

U indicates not detected at detection limit shown

MATRIX SPIKE RESULTS

Omni Solv Water Lot No. 30255

Spike Added
Concentration
% Recovery

Omni Solv Water Lot No 30255 DUP

Spike Added
Concentration
% Recovery

Relative Percent Difference

257-30 Rep 1

Spike Added
Concentration
% Recovery

257-30 DUP Rep 1

Spike Added
Concentration
% Recovery

Relative Percent Difference

257-30 Rep 2

Spike Added
Concentration
% Recovery

257-30 DUP Rep 2

Spike Added
Concentration
% Recovery

Relative Percent Difference

U = Undetected.

. = Sample diluted 1:50

.. = Sample diluted 1:100.

(a) = Values outside of QC limits.

	Lindane Heptachlor		Aldrin		Dieldrin		Endrin		4,4'-DDT		Surrogate Recovery DBC
0.627	0.627		0.627		0.627		0.627		0.627		0.160
0.398	0.230		0.202		0.382		0.508		0.427		0.0957
63%	37%	(a)	32%	(a)	61%		81%		66%		60%
0.597	0.597		0.597		0.597		0.597		0.597		0.152
0.431	0.407		0.394		0.407		0.497		0.473		0.100
72%	68%		66%		68%		83%		79%		66%
13%	59%	(a)	69%	(a)	9%		2%		15%		
1.53	1.53		1.53		1.53		1.53		1.53		0.390
1.09	1.01		0.863		1.22		1.39		1.42		0.367
71%	66%		66%		80%		91%		93%		94%
1.45	1.45		1.45		1.45		1.45		1.45		0.369
0.979	0.828		0.675		1.13		1.30		1.37		0.349
68%	57%		46%		78%		90%		94%		85%
4%	15%		20%		2%		1%		1%		
1.53	1.53		1.53		1.53		1.53		1.53		0.390
1.12	1.06		0.907		1.17		1.17		1.17		0.317
73%	70%		59%		76%		76%		76%		81%
1.45	1.45		1.45		1.45		1.45		1.45		0.369
0.892	0.865		0.694		0.943		0.935		0.916		0.253
57%	60%		47%		63%		64%		63%		68%
25% (a)	14%		23%	(a)	16%		17%		19%		

METALS RESULTS FOR RICHMOND WATERS

WES - RICHMOND (CF #257)

Sponsor: C. Price/ R. Brannon

(Concentrations in ug/L, ppb)

MSL CODE	REPS	SPONSOR CODE	Ag ICP-MS	As AA	Cd ICP-MS	Cr ICP-MS	Cu ICP-MS	Hg CVAA	Ni ICP-MS	Pb ICP-MS	Se ICP-MS	Zn ICP-MS
257 49		RANSMD1-1	0.06	20.27	1.15	6.46	11.50	0.022	17.40	0.65	28.40	24.1
257 50	REP 1	RANSMD1-2	0.09	27.80	1.01	6.72	7.77	0.856	13.60	1.04	26.50	40.1
257 50	REP 2	RANSMD1-2	0.14	-	-	-	-	0.101	-	-	-	-
257 51		RANSMD1-3	-	31.57	0.58	5.78	10.10	0.012	23.30	0.60	26.40	157.0
257 52		RANSMD2-1	0.10	23.17	1.17	5.38	46.80	0.010	11.10	22.30	2.58	30.3
257 53		RANSMD2-2	0.14	21.43	1.47	7.40	42.90	0.015	10.60	17.40	5.72	31.8
257 54		RANSMD3-2	0.09	28.38	1.33	5.88	33.10	0.019	10.80	18.10	4.74	83.5
257 55		RANSMD3-1	0.04	49.67	2.26	67.60	381.00	0.005	70.20	128.00	2.30	267.0
257 56		RANSMD3-2	0.08	62.91	2.79	68.30	373.00	0.022	68.00	161.00	2.95	249.0
257 57		RANSMD3-3	0.07	38.81	3.91	72.50	383.00	0.021	70.90	173.00	2.85	203.0
257 58		RANSMD4-1	0.11	52.98	5.00	211.00	582.00	0.079	167.00	159.00	5.36	661.0
257 59	REP 1	RANSMD4-2	0.11	66.22	5.43	211.00	542.00	0.058	146.00	170.00	3.87	512.0
257 59	REP 2	RANSMD4-2	0.12	-	-	-	-	0.078	-	-	-	-
257 60		RANSMD4-3	-	44.02	6.13	153.00	628.00	0.154	140.00	251.00	3.23	408.0
257 61		RANSMD5-1	0.18	44.31	2.18	37.00	131.00	0.178	35.10	43.50	3.73	93.1
257 62		RANSMD6-2	0.10	72.84	5.06	38.50	160.00	0.291	47.90	50.20	1.84	159.0
257 63		RANSMD5-3	0.16	76.15	2.00	44.10	193.00	0.023	42.00	58.40	2.93	113.0
257 64	Rep 1	RANSMD6-1	0.07	24.04	0.49	12.30	29.60	0.010	6.24	5.95	3.47	107.0
257 64	Rep 2	RANSMD6-1	0.11	24.91	0.52	13.00	31.80	-	6.09	6.48	3.72	107.0
257 65		RANSMD6-2	0.07	39.98	1.72	15.90	71.30	0.050	15.40	22.20	2.14	133.0
257 66		RANSMD6-3	0.13	62.91	1.99	20.30	105.00	0.494	24.90	33.00	3.01	102.0
257 67		RANSMDH2O BLK	0.13	0.50 U	0.22	0.66	9.58	0.002	0.44	0.51	1.16	14.8
257 68		RANKM6HR-1	0.08	13.03	0.22	10.30	12.90	0.376	19.40	0.40	33.00	44.9
257 69		RANKM6HR-2	0.07	11.87	0.40	9.20	23.80	0.024	22.60	1.69	35.90	237.0
257 70	REP 1	RANKM6H3-3	0.09	16.80	0.18	9.72	16.90	0.014	22.90	0.50	38.30	20.8
257 70	REP 2	RANKM6H3-3	-	-	-	-	-	0.049	-	-	-	-
257 71		RANKMD1-1	0.12	24.91	0.61	8.11	15.10	0.046	19.30	0.95	26.80	25.2
257 72		RANKMD1-2	0.07	28.38	0.49	11.10	16.00	0.042	23.50	1.84	32.30	148.0
257 73		RANKMD1-3	0.10	24.04	0.76	7.79	13.90	0.040	23.10	1.07	31.30	38.4
257 74		RANKMD2-1	0.18	25.19	0.80	10.70	25.80	0.154	27.70	3.65	34.40	64.0
257 75		RANKMD2-2	0.14	38.52	0.33	14.40	16.80	0.069	18.80	2.54	31.60	38.7
257 76		RANKMD2-3	0.10	30.7	0.43	10.60	24.20	0.116	25.90	3.86	29.40	57.8
257 77		RANKMD3-1	0.13	72.84	0.31	14.40	15.80	0.021	22.50	0.54	34.40	19.0
257 78		RANKMD3-2	0.09	43.04	0.54	10.30	23.80	0.010	24.50	3.97	35.50	59.8
257 79		RANKMD3-3	0.05	43.04	0.14	6.82	16.50	0.008	14.50	1.59	27.40	27.1
257 80	REP 1	RANKMD7-1	0.06	132.44	0.29	9.47	14.20	0.011	23.00	0.82	31.50	13.3
257 80	REP 2	RANKMD7-1	-	-	-	-	-	0.013	-	-	-	-
257 81		RANKMD7-2	0.11	59.6	0.24	8.71	15.80	0.021	23.80	0.59	30.40	18.9
257 82		RANKMD7-3	0.09	129.13	1.62	10.50	21.10	0.010	69.40	30.60	29.40	261.0

METALS RESULTS FOR RICHMOND WATERS

WES - RICHMOND (CF #257)

Sponsor: C. Price/ R. Brannon

(Concentrations in ug/L, ppb)

MSL CODE	REPS	SPONSOR CODE	Ag ICP-MS	As AA	Cd ICP-MS	Cr ICP-MS	Cu ICP-MS	Hg CVAA	Ni ICP-MS	Pb ICP-MS	Se ICP-MS	Zn ICP-MS
257. 83		RANKMD10-1	0.13	82.78	0.24	9.71	17.10	0.033	22.90	0.69	37.80	36.8
257. 84	REP 1	RANKMD10-2	0.07	66.22	0.14	8.56	13.30	0.087	16.50	0.83	32.40	23.7
257. 84	REP 2	RANKMD10-2	0.16	-	-	-	-	0.086	-	-	-	-
257. 85		RANKMD10-3	0.05	86.09	0.23	12.70	28.00	0.022	25.00	2.63	30.80	58.3
257. 86		RANKMH2O BLK	0.05	0.50 U	0.10	1.31	9.81	0.005	0.56	0.26	4.65	10.0
257. 87		RANSMD7-1	0.01	9.85	0.55	4.57	23.60	0.006	5.57	5.84	4.36	86.5
257. 88	Rep 1	RANSMD7-2	0.03	12.16	0.50	4.97	24.10	0.007	3.94	6.08	3.47	28.1
257. 88	Rep 2	RANSMD7-2	0.05	12.45	0.50	5.09	25.50	-	3.72	5.91	4.07	28.1
257. 89		RANSMD7-3	0.04	15.64	1.36	12.80	51.70	0.020	13.50	15.80	4.42	59.9

U indicates not detected at detection limit shown

METALS RESULTS FOR RICHMOND WATERS

WES - RICHMOND (CF #257)

Sponsor: C. Price/ R. Brannon

(Concentrations in ug/L, ppb)

SPONSOR CODE	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
	ICP-MS	AA	ICP-MS	ICP-MS	ICP-MS	CVA	ICP-MS	ICP-MS	ICP-MS	ICP-MS
STANDARD REFERENCE MATERIAL										
1641b	-	-	-	-	-	1.52	-	-	-	-
Certified	-	-	-	-	-	1.52	-	-	-	-
Value	-	-	-	-	-	-	-	-	-	-
1643b	9.34	-	19.30	16.40	19.50	-	40.90	26.50	8.67	67.2
Certified	9.80	-	20.00	18.60	21.90	-	49.00	23.70	9.70	66.0
Value	±0.8	-	±1.0	±0.4	±0.4	-	±3.0	±0.7	±0.5	±2.0
1643b	10.30	-	21.00	19.40	22.40	-	48.80	25.00	11.20	77.8
Certified	9.80	-	20.00	18.60	21.90	-	49.00	23.70	9.70	66.0
Value	±0.8	-	±1.0	±0.4	±0.4	-	±3.0	±0.7	±0.5	±2.0
CASS-2	-	1.16	-	-	-	-	-	-	-	-
Certified	-	1.01	-	-	-	-	-	-	-	-
Value	-	±0.07	-	-	-	-	-	-	-	-
SLRS-2	-	0.50 U	-	-	-	-	-	-	-	-
Certified	-	0.77	-	-	-	-	-	-	-	-
Value	-	±0.09	-	-	-	-	-	-	-	-
MATRIX SPIKE RESULTS										
257-73 + Spike	5.22	62.84	6.33	29.70	32.80	-	44.40	6.02	50.30	59.4
Spike Concentration Recovered	5.12	42.86	5.57	21.90	18.90	-	21.30	5.00	19.00	21.1
Amount Spiked	5.00	38.80	5.00	20.00	20.00	-	20.00	5.00	20.00	20.0
Percent Recovery	102%	91%	111%	110%	95%	-	107%	100%	95%	106%
257-83 + Spike	4.69	39.13	5.37	9.71	36.20	-	42.60	4.75	51.50	58.2
Spike Concentration	4.56	37.02	5.13	34.70	19.00	-	19.60	4.10	13.70	21.4
Amount Spiked	5.00	37.02	5.00	20.00	20.00	-	20.00	5.00	20.00	20.0
Percent Recovery	91%	95%	103%	174%	95%	-	98%	82%	69%	107%

WES - BALDWIN
COLUMN LEACHING (CF #357)
PESTICIDE CONCENTRATIONS IN WATER

ADDENDUM
4/29/92

(Concentrations in ug/L)

MSL Code	357-27	Blank
Sponsor ID	RO-9-10	Blank
Aldrin	0.06 U	0.06 U
A-BHC	0.06 U	0.06 U
B-BHC	0.06 U	0.06 U
D-BHC	0.06 U	0.06 U
Chlordane (Gamma)	0.06 U	0.06 U
Chlordane (Alpha)	0.06 U	0.06 U
4,4'-DDD	0.95	0.06 U
4,4'-DDE	0.09 P	0.06 U
4,4'-DDT	0.06 U	0.06 U
Dieldrin	0.15	0.06 U
Endosulfan I	0.06 U	0.06 U
Endosulfan II	0.06 U	0.06 U
Endosulfan Sulfate	0.06 U	0.06 U
Endrin	0.06 U	0.06 U
Endrin Aldehyde	0.06 U	0.06 U
Heptachlor	0.06 U	0.06 U
Heptachlor Epoxide	0.06 U	0.06 U
Lindane (G-BHC)	0.06 U	0.06 U
Toxaphene	0.60 U	0.60 U
Methoxychlor	0.12 U	0.12 U
Endrin Ketone	0.06 U	0.06 U
DBC Surrogate Recovery (%)	97%	68%

U = Indicates compound was analyzed for but not detected.

P = This flag is used for a pesticide/Aroclor target analyte when there is greater than 25% difference for detected concentrations between the two GC columns. The lower of the two values is reported.

WES - BALDWIN
COLUMN LEACHING (CF #357)
PAH CONCENTRATIONS IN WATER

ADDENDUM
4/29/92

(Concentrations in ug/L)

MSL Code	357-28	357-29	Blank
Sponsor ID	RO-14-9	RO-14-10	Blank
Sample Volume (L)	1.3	1.2	1.0
naphthalene	30	35	20 U
acenaphthylene	15 U	20	20 U
acenaphthene	15 U	17 U	20 U
fluorene	15 U	17 U	20 U
phenanthrene	32	41	20 U
anthracene *	33	39	20 U
fluoranthene	44	86	20 U
pyrene	310	267	20 U
benz[a]anthracene	21	49	20 U
chrysene	19	55	20 U
benzofluoranthene *	407	481	40 U
benzo[a]pyrene	188	185	20 U
indeno[1,2,3-c,d]pyrene	74	99	20 U
dibenz[a,h]anthracene	24	27	20 U
benzo[g,h,i]perylene	109	140	20 U

% Surrogate Recoveries

fluorene-d10	87%	84%	84%
anthracene-d10	92%	81%	85%
pyrene-d10	101%	96%	94%

U = Undetected at given method detection limit

* = All benzofluoranthene isomers (b, j & k) are quantified together

357TBT.DATA

WES-RICHMOND
 COLUMN LEACHING (CF#357)
 TBT CONCENTRATIONS
 IN WATER SAMPLES
 (concentrations in ug/L)

11/20/91

MSL Code	Sponsor Code	Tripentyl % Surrogate	Tetra Tin		Tributyl Tin		Dibutyl Tin		Monobutyl Tin	
357-5	RO-15-1	78.8	1.5	U	1.7	U	7.1		1.4	U
357-6	RO-15-2	93.3	1.4	U	1.6	U	11.7		2	
357-7	RO-15-3	95.5	1.2	U	1.3	U	9.4		1.6	
357-8	RO-15-4	86.2	1.5	U	1.7	U	9.0		2.7	
357-9	RO-15-5	41.8	1.4	U	1.6	U	1.7		1.3	U
357-23	RO-15-6	62.3	1.0		1.6		4.1		1.2	
357-24	RO-15-7	56.4	1.4		1.6		6.0		1.2	
357-25	RO-15-8	26.7	1.0		4.5		8.3		2.3	
357-26	RO-15-9	65.4	1.0		11.3		24.5		8.1	
357-30	RO-15-10	14.8	8.9	U	21.6	U	6.5	J	12.2	U

BLANK AND MATRIX SPIKE RECOVERIES

BLANK-1	86.6	1.6	U	1.9	U	1.7	U	1.5	U
BLANK-2	45.3	0.5	U	0.5	U	0.9	U	0.5	U

357BLANK-1 SPIKE	68.1	37.7		57.3		63.3		15.2	
% Recovery		38%		57%		63%		NS	

357BLANK-2 SPIKE	47.0	11.4		25.3		45.8		5.6	
% Recovery		11%		25%		46%		NS	

NS = Indicates not spiked.

U = Indicates analyte not detected above detection limits.

J = Indicates value detected below the detection limits.

WES-BALOWIN
COLUMN LEACHING (CF #357)
PAH CONCENTRATIONS IN WATER

11/20/91

(concentrations in ng/L (ppt))													
MSL Code	357-10	357-11	357-12	357-13	357-19	357-20	357-21	357-22	Procedural	Blank Spike	Blank Spike	Blank Spike	Dup
Sponsor ID	RO-14-1	RO-14-2	RO-14-3	RO-14-4	RO-14-5	RO-14-6	RO-14-7	RO-14-8	Blank	% Recovery	% Recovery	% Recovery	
Sample Volume (L)	1.376	1.281	0.949	0.982	1.079	1.102	1.220	1.281	1.000	1.000	1.000	1.000	
naphthalene	7.3 U	7.3 U	50.1	57.8	25.5	20.7	23.6	25.7	3.0 J	75	75	70	
acenaphthylene	9.2 U	9.2 U	9.2 U	9.2 U	18.5 U	18.1 U	24.4	17.7	9.2 U	NA	NA	NA	
acenaphthene	5.9 U	5.9 U	5.9 U	5.9 U	18.5 U	18.1 U	16.4 U	15.6 U	5.9 U	NA	NA	NA	
fluorene	6.9 U	6.9 U	10.0	8.7	18.5 U	18.1 U	18.2	15.6 U	6.9 U	85	85	78	
phenanthrene	7.8 U	7.8 U	18.9	20.7	18.5 U	30.3	50.0	36.5	7.8 U	NA	NA	NA	
anthracene	11.5 U	11.5 U	11.5 U	7.4	18.5 U	27.8	55.0	39.1	11.5 U	79	79	75	
fluoranthene	5.9 U	3.9 J	6.9	13.5	18.5 U	76.4	134.8	100.6	5.9 U	90	90	89	
pyrene	4.3 U	6.3 J	13.5	24.4	40.9	280.9	528.8	406.3	6.5 U	NA	NA	NA	
benz[a]anthracene	30.0 U	30.0 U	30.0 U	30.0 U	18.5 U	28.5	65.0	49.0	19.2 U	81	81	73	
chrysene	19.2 U	19.2 U	19.2 U	6.3 J	18.5 U	48.5	82.2	63.9	14.7 U	NA	NA	NA	
benzo[b]fluoranthene	14.7 U	14.7 U	14.7 U	14.3 J	57.3 *	457.8 *	965.2	746.0	13.3 U	NA	NA	NA	
benzo[k]fluoranthene	13.3 U	13.3 U	13.3 U	10.5 J	NA	NA	NA	NA	NA	NA	NA	NA	
benzo[a]pyrene	5.4 U	6.4 U	6.4 U	11.9	23.3	162.2	335.9	266.5	6.4 U	100	100	89	
indeno[1,2,3-c,d]pyrene	20.7 U	20.7 U	20.7 U	17.3 J	18.5 U	25.7	88.1	55.9	20.7 U	NA	NA	NA	
dibenz[a,h]anthracene	21.6 U	21.6 U	21.6 U	21.6 U	18.5 U	18.1 U	19.3	15.6 U	21.6 U	NA	NA	NA	
benzo[g,h,i]perylene	20.0 U	20.0 U	20.0 U	17.9 J	18.5 U	45.9	156.6	89.9	20.0 U	127	127	119	
naphthalene-d8 (% Rec)	77	81	72	78	87	86	80	84	95	421	421	379	
acenaphthene-d10 (% Rec)	82	84	75	80	77	85	83	86	94	394	394	365	
benzo[a]pyrene-d12 (% Rec)	82	90	87	88	89	90	87	91	94	453	453	429	

U - Not detected, reprinted as MDL in ng/L

J - Value below MDL

* - Benzo[a]fluoranthene isomers are quantified together

NA - Not applicable

WES - RICHMOND
COLUMN LEACHING (CF#357)
PESTICIDE CONCENTRATIONS
IN WATER SAMPLES

10/11/91

(concentrations in ug/L)

Sample Name	Sponsor Code	(Lindane)				Hepta- chlor Epoxide	Endo- sulfan I	Diel- drin	4,4'- DDE	Endrin
		Alpha- BHC	Beta- BHC	Delta- BHC	Gamma- Chlordane	Hepta- chlor				
357-1	RO-9-1	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
357-2	RO-9-2	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
357-4	RO-9-3	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
357-3	RO-9-4	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
357-14	RO-9-5	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
357-15	RO-9-6	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.13 P	0.06 U	0.06 U
357-16	RO-9-7	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.21	0.1 P	0.06 U
357-17	RO-9-8	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.16 P	0.12 P	0.06 U
Blank		0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U	0.06 U
Matrix Spike		0.06 U	0.06 U	0.06 U	0.35	0.11	0.06 U	0.33	0.06 U	0.4
Matrix Spike Dup		0.06 U	0.06 U	0.06 U	0.35	0.11	0.06 U	0.34	0.06 U	0.4

U = Indicates analyte not detected above the detection limit.

P = Used for a pesticide/Aroclor target analyte when there is greater than 25% difference for detected concentrations between the two GC columns.
The lower of the two values is reported.

WES - RICHMOND
COLUMN LEACHING (CF#357)
PESTICIDE CONCENTRATIONS
IN WATER SAMPLES
(concentrations in ug/L)

Sample Name	Sponsor Code	Endo-Sulfan II	4,4'-DDD	Endo-Sulfate	4,4'-DDT	Methoxy-chlor	Endrin Ketone	Gamma-Chlordane	Alpha-Chlordane	Toxaphene	Surrogate % Dibutyl-chlorodanate
357-1	RO-9-1	0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.6 U	63
357-2	RO-9-2	0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.6 U	102
357-4	RO-9-3	0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.6 U	70
357-3	RO-9-4	0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.6 U	32
357-14	RO-9-5	0.06 U	0.12	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.6 U	21
357-15	RO-9-6	0.06 U	0.55	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.6 U	59
357-16	RO-9-7	0.06 U	1.1	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.6 U	43
357-17	RO-9-8	0.06 U	1.1 P	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.6 U	27
Blank		0.06 U	0.06 U	0.06 U	0.06 U	0.12 U	0.06 U	0.06 U	0.06 U	0.6 U	79
Matrix Spike		0.06 U	0.06 U	0.06 U	0.43	0.12 U	0.06 U	0.06 U	0.06 U	0.6 U	122
Matrix Spike Dup		0.06 U	0.06 U	0.06 U	0.45	0.6 U	0.06 U	0.06 U	0.06 U	0.12 U	84

U = Indicates analyte not detected above the detection limit.

P = Used for a pesticide/Aroclor target analyte when there is greater than 25% difference for detected concentrations between the two GC columns.
The lower of the two values is reported.

357PEST.DATA

WES - RICHMOND
COLUMN LEACHING (CF#357)
PESTICIDE CONCENTRATIONS
IN WATER SAMPLES

10/11/91

MATRIX SPIKE RECOVERIES

Matrix Spike
Spike Added
Spike Recovered
Percent Recovery

Matrix Spike
Spike Added
Spike Recovered
Percent Recovery

(concentrations in ug/L)				
Lindane	Heptachlor	Aldrin	Dieldrin	Endrin
0.50	0.50	0.50	0.50	0.50
0.35	0.11	0.057	0.33	0.40
72%	22% *	11% *	66%	80%
				86%
0.50	0.50	0.50	0.50	0.50
0.35	0.11	0.06	0.34	0.40
70%	22% *	12% *	68%	80%
				90%

* - Values outside QC limits.

1/8/92

WES RICHMOND (CF #322)
WATER METAL RESULTS
(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	AA	AA	ICP-MS	ICP-MS	CYAA	ICP-MS
1% HNO ₃		1 U	0.01 U	1 U	1 U	NA	NA	0.03	0.01 U	NA	1 U
322-35	RM-7-14	30.7	35.4	55.5	64.5	18.13	1.06 U	0.08	0.42	0.00104	20.4
322-36 Rep 1	RM-7-15	57.5	48.7	90.3	80.5	16.70	1.06 U	1.05	0.07	0.25956	36.1
322-36 Rep 2	RM-7-15	61.5	50.2	94.4	90.8	17.68	1.06 U	0.87	0.38	0.25221	36.7
322-37	RM-7-16	67.1	79.2	134	161	21.95	1.06 U	0.18	1.23	0.00247	49.1
322-38	RM-7-17	97.0	113	192	237	21.00	1.06 U	0.18	1.51	0.00397	74.8
322-39	RM-7-18	NA	NA	NA	NA	34.83	1.22	NA	NA	0.09396	NA
322-40	RM-7-19	135	191	307	400	19.56	1.06 U	0.04	2.82	0.00034	131
322-41	RM-7-20	289	277	438	515	20.04	1.22	1.86	2.90	0.23456	178
322-42	RM-7-21	207	215	329	413	18.61	1.83	0.53	2.08	0.01548	142
322-43	RM-7-22	142	164	251	339	15.75	1.22	0.17	2.36	0.02258	109
322-44	RM-7-24	26.8	38.2	48.9	288	10.50	1.06 U	0.06	1.66	0.00050	68.5
322-45	RM-7-25	24.9	17.5	63.7	212	14.32	1.06 U	0.05	1.60	0.00492	94.2
322-46	RM-7-26	48.8	36.1	162	247	19.09	1.06 U	0.93	3.20	0.02969	127
322-47	RM-8-13	102	86.3	134	135	18.13	1.06 U	0.80	1.30	0.40913	55.5
322-48	RM-8-14	36.1	49.6	25.7	204	21.95	1.06 U	0.06	1.12	0.00112	59.5
322-49	RM-8-15	116	128	231	305	20.04	1.06 U	0.18	2.02	0.06230	82.5
322-50	RM-8-16	170	151	274	311	20.52	1.06 U	0.88	2.60	0.02581	120
322-51	RM-8-17	152	140	221	309	18.61	1.06 U	0.29	1.92	0.00591	105
322-52	RM-8-18	19.9	19.9	24.6	108	20.04	1.06 U	0.04	0.76	0.00313	44.8
322-53	RM-8-19	42.5	34.8	53.2	219	17.66	1.06 U	0.15	1.47	0.00413	73.8
322-54	RM-8-20	120	143	271	403	19.09	1.06 U	0.08	2.07	0.00078	105
322-55	RM-8-21	261	228	368	484	19.09	1.06 U	1.82	2.95	0.34150	162

U = Analyte not detected above detection limits.

1/8/92

WES RICHMOND (CF #322)
WATER METAL RESULTS
(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	AA	AA	ICP-MS	ICP-MS	CVA	ICP-MS
322-56	RM-8-22	25.2	27.4	17.3	193	15.27	1.06 U	0.03	1.09	0.00089	65.0
322-57	RM-8-23	29.4	25.1	98.4	224	23.86	1.06 U	0.06	1.75	0.08690	116
322-58	RM-8-24	29.2	10.8	121	150	21.95	1.06 U	0.40	1.39	0.01781	87.9
322-59	RM-9-10	4.57	165	152	1 U	20.52	1.83	0.46	0.24	0.01107	1 U
322-60	RM-9-11	1.88	98.7	1.80	3.03	21.95	1.22	0.12	<0.01	0.00558	1 U
322-61	RM-9-12	1.57	74.2	2.57	2.00	26.72	1.06 U	0.07	0.25	0.00846	1 U
322-62	RM-9-13	2.05	77.6	1.15	6.22	22.43	1.06 U	0.04	0.02	0.01012	1 U
322-63	RM-9-14	3.34	66.1	2.78	3.11	21.95	1.06 U	0.03	0.01	0.00552	1 U
322-64	RM-9-15	3.28	43.5	10.1	7.33	25.29	1.22	0.05	0.02	0.00729	1 U
322-65	Rep 1 RM-9-16	17.5	42.7	26.2	16.1	24.81	1.06 U	0.19	0.30	0.04217	8.07
322-65	Rep 2 RM-9-16	17.5	45.5	25.9	17.6	23.86	1.06 U	0.09	0.02	0.04484	7.93
322-66	RM-9-17	7.08	30.8	25.8	1 U	22.90	1.22	0.50	<0.01	0.05219	11.5
322-67	RM-9-18	13.9	31.4	32.0	33.5	21.00	1.06 U	0.11	0.11	0.00394	14.3
322-68	RM-9-19	25.4	29.2	34.4	7.21	12.41	1.06 U	0.44	0.08	0.13761	12.8
322-69	RM-9-20	7.21	14.0	14.9	19.9	15.75	1.06 U	0.04	0.78	0.01678	7.06
322-70	RM-9-21	4.62	10.7	13.2	13.0	12.88	1.06 U	0.05	0.10	0.00195	7.01
322-71	RM-8-25	19.1	16.7	45.8	142	17.18	1.06 U	0.05	0.86	0.01968	54.1
322-72	RM-8-26	51.8	58.9	121	154	12.41	1.06 U	0.13	1.06	0.00698	53.2
322-73	RM-9-22	10.1	17.5	19.7	17.1	13.36	1.06 U	0.05	0.18	0.00490	7.63
322-74	RM-9-23	13.1	24.0	28.0	36.5	115.27	1.06 U	0.06	0.21	0.00286	13.6
322-75	RM-9-24	7.29	13.8	20.1	34.0	12.41	1.06 U	0.07	0.43	0.00669	12.5
322-76	RM-9-25	6.32	11.6	18.2	103	10.50	1.06 U	0.05	0.31	0.00297	8.33
322-77	RM-9-26	9.17	15.5	22.1	27.8	11.45	1.06 U	0.07	0.18	0.00544	9.61

U = Analyte not detected above the detection limits

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WES RICHMOND (CF #322)
WATER METAL RESULTS
(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As AA	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
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STANDARD REFERENCE MATERIAL

1643b Rep 1		18.6	49.0	22.6	73.4	NA	NA	10.7	20.8	NA	20.2
1643b Rep 2		20.0	54.8	25.9	81.3	NA	NA	11.1	20.9	NA	21.5
	certified value	0.36	1.07	3.58	1.34	NA	NA	NC	0.015	NA	0.106
		±0.04	±0.08	±0.3	±0.2	NA	NA	NC	±0.002	NA	±0.011
1643c		NA	NA	NA	NA	NA	13.4	NA	NA	NA	NA
	certified value	NA	NA	NA	NA	NA	12.7	NA	NA	NA	NA
		NA	NA	NA	NA	NA	±0.7	NA	NA	NA	NA
SLRS Rep 1		1 U	0.06	3.45	1 U	NA	NA	0.03	0.04	NA	1 U
SLRS Rep 2		1 U	0.05	3.56	1 U	NA	NA	0.07	0.05	NA	1 U
	certified value	18.6	49	21.9	66	NA	NA	9.8	20	NA	23.7
		±0.4	±3	±0.4	±2	NA	NA	±0.8	±1	NA	±0.7
1641b Rep 1		NA	NA	NA	NA	NA	NA	NA	NA	1.46	NA
	certified value	NA	NA	NA	NA	NA	NA	NA	NA	1.52	NA
		NA	NA	NA	NA	NA	NA	NA	NA	±0.08	NA

U = Analyte not detected above the detection limits.
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NC = Not certified.

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WES RICHMOND (CF #322)
WATER METAL RESULTS
 (concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr	Ni	Qu	Zn	As	Se	Ag	Cd	Hg	Pb
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	AA	AA	ICP-MS	ICP-MS	CVA	ICP-MS

MATRIX SPIKE RESULTS

Amount Spiked	20	20	20	20	20	21.95	42.86	100	1	50	5
322-50 + Spike	180	175	262	277	277	42.95	40.85	1.03	3.29	0.0672	117
322-50	170	151	274	311	311	20.04	1.06 U	0.68	2.6	0.0258	120
Amount Recovered	10	24	-12	-34	-34	22.91	40.85	0.35	0.69	0.0414	-3
Percent Recovery	50%	120%	-60%	-170%	-170%	104%	95%	0%	69%	83%	-60%
Amount Spiked	20	20	20	20	20	21.95	42.86	100	1	50	5
322-68 + Spike	43.9	29.2	64.6	32.0	32.0	37.7	45.12	0.86	1.92	0.1033	16.1
322-68	25.4	31.4	34.4	7.21	7.21	12.41	1.06 U	0.44	0.08	0.0522	12.8
Amount Recovered	18.5	-2.2	30.2	24.79	24.79	25.29	45.12	0.42	1.84	0.0511	3.3
Percent Recovery	93%	-11%	151%	124%	124%	115%	105%	0%	184%	102%	66%

U = Analyte not detected above the detection limits.

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WES RICHMOND (CF #322)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As AA	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
1% HNO3 Rep 1		0.32	0.01 U	0.01 U	0.33	NA	NA	0.01 U	0.01 U	NA	0.01 U
1% HNO3 Rep 2		0.1 U	0.5 U	0.1 U	0.1 U	NA	NA	0.05	0.06	NA	0.1 U
322-1	RM-7-1	143	613	4.39	29.1	17.18	0.71 U	0.05	0.18	0.0298	0.61
322-1	RM-7-1	155	566	4.11	27.5	NA	0.71 U	0.01 U	0.12	NA	0.32
322-2	RM-7-2	60.5	365	9.02	21.9	24.34	0.71 U	0.04	0.00	0.01992	0.57
322-3	RM-7-3	46.1	328	12.2	25.2	23.38	0.71 U	0.02	0.03	0.01625	1.53
322-4	RM-7-4	26.2	193	3.20	23.4	20.52	0.71 U	0.00	0.02	0.01904	0.39
322-5	RM-7-5	17.5	141	2.21	19.5	21.48	0.71 U	0.01	0.01	0.01869	0.15
322-6	RM-7-6	9.30	111	6.12	23.4	21.48	0.71 U	0.02	0.01 U	0.02768	0.05
322-7	RM-7-7	9.84	101	21.7	17.8	17.68	0.71 U	0.01 U	0.01 U	0.0064	1.80
322-8	MR-7-8	5.68	79.0	5.89	16.4	20.04	0.71 U	0.01 U	0.01 U	0.00573	0.17
322-9	RM-7-9	1.72	42.3	4.85	9.84	23.38	0.71 U	1.0 U	0.01 U	0.00843	0.05
322-10	RM-7-10	4.50	43.1	5.32	21.5	23.38	0.71 U	0.00	0.01 U	0.01091	0.49
322-11	RM-7-11	3.33	23.6	9.98	23.2	18.61	0.71 U	0.02	0.13	0.03243	1.17
322-12	RM-7-12	2.74	19.1	10.2	20.0	18.61	0.71 U	0.04	0.06	0.03892	2.35
322-13	RM-7-13	9.41	18.9	18.4	37.1	23.38	0.71 U	0.04	0.18	0.05671	9.00
322-13	RM-7-13	7.84	15.6	14.5	408	NA	0.71 U	0.16	0.24	NA	7.43
322-14	RM-8-1	72.1	800	8.02	173	34.36	0.71 U	0.03	0.05	0.0182	0.81
322-14	RM-8-1	81.0	795	4.89	175	NA	0.71 U	0.16	0.29	NA	0.45
322-15	RM-8-2	16.6	383	4.53	47.7	38.17	0.71 U	0.00	0.13	0.01155	0.47
322-15	RM-8-2	17.8	353	2.25	45.5	NA	0.71 U	0.01 U	0.14	NA	0.1 U
322-16	RM-8-3	8.57	85.8	3.01	36.5	38.27	0.71 U	0.05	0.07	0.02481	0.26
322-17	RM-8-4	2.69	65.9	7.49	24.5	42.47	0.71 U	0.06	0.10	0.01984	0.09
322-18	RM-8-5	1.45	38.1	6.83	19.3	37.70	0.71 U	0.03	0.08	0.00892	0.07
322-19	RM-8-6	1.54	35.1	7.80	15.8	28.15	0.71 U	0.16	0.08	0.01163	0.31
322-20	RM-8-20	1.61	29.2	7.49	15.0	27.68	0.71 U	0.03	0.02	0.00597	0.12

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WES RICHMOND (CF #322)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	AA	AA	ICP-MS	ICP-MS	CVA	ICP-MS
322-21 Rep 1	RM-8-8	2.54	24.8	5.11	16.8	28.63	0.71 U	0.01 U	0.02	0.00747	0.13
322-21 Rep 1a	RM-8-8	2.02	20.9	0.1 U	286	NA	NA	0.01	0.08	NA	0.1 U
322-21 Rep 2	RM-8-8	2.56	22.7	4.63	274	28.15	0.71 U	0.13	0.01 U	0.00771	0.23
322-21 Rep 2a	RM-8-8	1.72	19.9	0.1 U	9.36	NA	NA	0.50	0.04	NA	0.1 U
322-22	RM-8-9	2.59	20.9	8.7	15.6	29.58	0.71 U	0.02	0.04	0.01493	0.74
322-23	RM-8-10	4.48	18.2	11.6	20.8	24.81	0.71 U	0.06	0.06	0.0288	2.17
322-24	RM-8-11	7.58	16.4	14.9	223	22.43	0.71 U	0.06	0.23	0.05327	8.34
322-25	RM-8-12	15.2	26.2	28.3	49.6	23.38	0.71 U	0.01	0.31	0.00787	14.3
322-26	RM-9-1	62.2	114	25.9	124	12.88	0.71 U	0.23	1.09	0.02226	2.44
322-27	RM-9-2	17.3	71.6	7.43	21.5	15.27	0.71 U	0.03	0.23	0.00836	0.95
322-28	RM-9-3	2.45	52.4	6.34	17.2	13.38	0.71 U	0.03	0.25	0.01074	0.50
322-29	RM-9-4	2.05	48.2	5.34	12.4	12.41	0.71 U	0.01	0.14	0.00885	0.37
322-30	RM-9-5	1.24	39.4	4.13	14.4	12.41	0.71 U	0.02	0.08	0.01155	0.26
322-31	RM-9-6	1.54	76.1	0.94	11.5	1.65 U	0.71 U	0.03	0.11	0.00202	0.09
322-32	RM-9-7	3.19	48.8	0.24	15.0	11.45	0.71 U	0.02	0.07	0.00631	0.38
322-33	RM-9-8	2.52	56.8	5.94	12.9	9.54	0.71 U	0.07	0.04	0.00777	0.94
322-34 Rep 1	RM-9-9	1.05	38.0	0.28	13.8	14.79	0.71 U	0.03	0.07	0.00745	0.20
322-34 Rep 2	RM-9-9	1.19	40.9	0.41	10.8	15.27	0.71 U	0.08	0.03	0.00939	0.22

U = Indicates analyte not detected above the detection limits.

NA = Indicates not applicable

() = Indicates value is suspect; values obtained for duplicate runs and different isotopes had significant variation.

1/8/92

WES RICHMOND (CF #322)
WATER METAL RESULTS
(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	AA	AA	ICP-MS	ICP-MS	CVAA	ICP-MS
STANDARD REFERENCE MATERIAL											
SLRS Rep 1		0.60	0.94	3.23	2.34	NA	NA	0.01 U	0.01 U	NA	0.03
SLRS Rep 2	certified values	0.1 U 0.36 ±0.04	1.79 1.07 ±0.06	3.19 3.58 ±0.3	2.95 1.34 ±0.2	NA NA NA	NA NA NA	0.02 NC NC	0.04 0.015 ±0.002	NA NA NA	0.24 0.106 ±0.011
1643b Rep 1		19.8	49.4	22.0	119	NA	NA	11.1	20.7	NA	20.8
1643b Rep 2	certified values	19.0 18.6 ±0.4	42.8 49 ±3	18.7 21.9 ±0.4	102 66 ±2	NA NA NA	NA NA NA	10.9 9.8 ±0.8	18.4 20 ±1	NA NA NA	23.1 23.7 ±0.7
1643c Rep 1		NA	NA	NA	NA	81.47	15.58	NA	NA	NA	NA
1643c Rep 2	certified values	NA NA NA	NA NA NA	NA NA NA	NA NA NA	81.47 8.10 ±1.2	NA 12.70 ±0.7	NA NA NA	NA NA NA	NA NA NA	NA NA NA
1641b Rep 1	certified values	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	1.40 1.52 ±0.05	NA NA NA

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1/8/92

WES RICHMOND (CF #322)
WATER METAL RESULTS
 (concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	AA	AA	ICP-MS	ICP-MS	CVAL	ICP-MS

MATRIX SPIKE RESULTS

Amount Spiked		20	20	20	20	21.95	21.95	100	1	100	5
322-20+spike		18.1	45.2	22.4	34.3	45.81	21.95	78.0	1.06	99.48	4.87
322-20	RM-8-20	1.61	29.2	7.49	15.0	27.68	0.71 U	0.03	0.02	5.97	0.12
Amount Recovered		16.503	15.96	14.946	19.25	18.13	21.95	77.961	1.0454	93.51	4.755
Percent Recovery		83%	80%	75%	96%	83%	100%	78%	105%	94%	95%
Amount Spiked		NA	NA	NA	NA	NA	NA	1	NA	NA	NA
322-20+spike 100x		NA	NA	NA	NA	NA	NA	0.88	NA	NA	NA
322-20	RM-8-20	NA	NA	NA	NA	NA	NA	0.03	NA	NA	NA
Amount Recovered		NA	NA	NA	NA	NA	NA	0.8479	NA	NA	NA
Percent Recovery		NA	NA	NA	NA	NA	NA	85%	NA	NA	NA
Amount Spiked		20	20	20	20	21.95	21.95	100	1	100	5
322-33+spike		24.0	75.8	25.6	25.7	31.97	20.53	63.0	0.89	105.76	4.91
322-33	RM-9-8	2.52	56.8	5.94	12.9	9.54	0.71 U	0.07	0.04	7.77	0.94
Amount Recovered		21.487	19.065	19.6887	12.861	22.43	20.53	62.946	0.8522	97.99	3.967
Percent Recovery		107%	95%	98%	64%	102%	94%	63%	85%	98%	79%
Amount Spiked		NA	NA	NA	NA	NA	NA	1	NA	NA	NA
322-33+spike 100x		NA	NA	NA	NA	NA	NA	0.81	NA	NA	NA
322-33	RM-9-8	NA	NA	NA	NA	NA	NA	0.07	NA	NA	NA
Amount Recovered		NA	NA	NA	NA	NA	NA	0.74	NA	NA	NA
Percent Recovery		NA	NA	NA	NA	NA	NA	74%	NA	NA	NA

NA = Indicates not applicable.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
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13. ABSTRACT (Maximum 200 words) <p>This report describes testing and evaluation performed by the Environmental Laboratory of the U.S. Army Engineer Waterways Experiment Station (WES) on sediment from the Santa Fe Channel of Richmond Harbor, California. Test protocols from the Corps' Management Strategy for Disposal of Dredged Material were used in the present evaluation to determine the potential for migration of contaminants into the effluent, surface runoff, and leachates at an undetermined upland disposal site. The upland site would be managed such that plants and animals would not be allowed to colonize the site. Therefore, plant and animal bioassays were not performed.</p> <p>Sediment was collected from Santa Fe Channel from core depths to -38 ft and transported to the WES for testing. Santa Fe Channel sediment metal concentrations were found to be in the range of those found in normal agricultural soils with the exception of nickel. Santa Fe Channel sediment contained nickel</p> <p style="text-align: right;">(Continued)</p>				
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13. ABSTRACT (Continued).

concentrations at the maximum concentration allowed in soils for agricultural production. Sediment butyltin concentrations were low, at 15 ppb, but were higher than those found at an upland reference disposal site at Twitchell Island. Santa Fe Channel sediment contained some polycyclic aromatic hydrocarbons (PAHs) at concentrations higher than Twitchell Island and were generally elevated in PAHs compared to other reference sediments. Santa Fe sediment contained 185 ppb DDT, and 202 ppb DDD, which has given rise to concern.

Effluent and surface runoff test results indicated no toxicity to sensitive aquatic organisms. Copper concentrations in effluent and arsenic in surface runoff were the only parameters exceeding assumed criteria or standards. A mixing zone of 2 to 1 for copper and 3 to 1 for arsenic will eliminate any potential water quality impacts.

Leachate test results indicated a potential for arsenic and chromium to leachate eventually in concentrations that may exceed the assumed drinking water quality criteria. The time required to reach maximum leachate contaminant concentrations may be on the order of hundreds of years, depending on climatic conditions and disposal site-specific engineering controls. Leachate generation rates can be reduced by reducing the surface area of the disposal site and by constructing a composite liner.

In summary, Santa Fe Channel sediments will require management of suspended solids in effluent and surface runoff and a mixing zone of less than 10 to 1 to meet the strictest assumed water quality criteria or standard. Depending on the location, the confined disposal site should have a reduced surface area and a composite liner to control leachate migration, especially if leachate can migrate to surface receiving waters.